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HANDLING, TRANSPORTATION, STORAGE, AND MARKETING OF PEACHES

A digest of recent contributions to the knowledge of physical and biological phases of the subject

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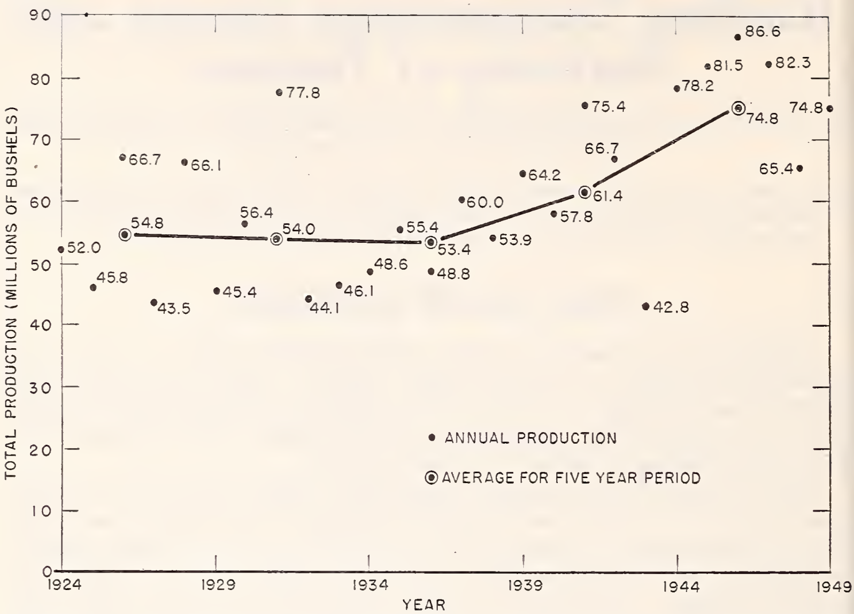

FIGURE 1.—Annual and 5-year average production of peaches in the United States, in millions of bushels, 1924–49. Data from USDA Agricultural Statistics.

sumption, it seems essential that immature fruit be eliminated and desirable that only firm or nearly tree-ripe fruit be marketed. If immature fruit is to be eliminated, establishment of an objective and reasonably accurate test for maturity will be necessary. Such a test would enable the inspection service to establish definitely whether or not the fruit is mature. Although considerable work has been done along this line, no entirely satisfactory test has been found.

If the more mature and relatively soft peaches are to be marketed, there is an urgent need for a container that will protect such soft fruit from bruising and that will be economical in cost and in labor for packing. Improvements in refrigeration during transit and in the speed with which the fruit is moved to market will also be needed. These factors will help insure that the fruit will pass through all market channels without excessive bruising and result in optimum quality for the consumer.

Decay of peaches during marketing has long been a serious problem. Development of more effective control measures is of primary importance.

Increased emphasis on research along the above lines has indicated the need for a review and digest of recent work on the handling, transportation, and marketing of peaches. This digest covers (1) the physical and biological aspects of the development of the fruit as it approaches maturity, and (2) its handling in the fresh state from harvest to the consumer. It does not cover the processing of the fruit or the economic phases of marketing.

PHYSICAL AND CHEMICAL CHANGES DURING MATURATION AND RIPENING

TERMINOLOGY

The terms "maturity" and "ripeness" have been used rather loosely and to some extent synonymously in horticultural literature, particularly in publications dealing with peaches. As used in this bulletin, "mature" emphasizes fullness of growth and completeness of development, and "ripe" suggests readiness for use. The accumulation of carbohydrates and other materials and the enlargement of the cells during growth and development of the fruit are maturity changes that influence the ultimate quality of the peaches when they become ripe. Softening of the fruit by hydrolysis of the pectic materials and the development of aromatic constituents are ripening changes that bring the fruit to a condition suitable for use. Maturation occurs only while the fruit is attached to the tree, but ripening may occur either before or after harvest.

The term "shipping ripe" is frequently used to describe peaches picked while still hard. This is an incorrect usage of "ripe," as fruit in this condition is definitely not suitable for consumption. This condition might better be described as "shipping mature." On the other hand, if the fruit is allowed to remain on the tree until soft and suitable for eating, it is correctly described as "tree ripe." The term "shipping ripe" may be used in this bulletin when citing publications in which this term is used, even though incorrectly. The definitions of the correct terms as given above are in accordance with their definitions in standard dictionaries but differ in many respects from their horticultural usage as proposed by Lott (*135*).

Terms in wide variety have been used to describe different stages of maturity. Lloyd and Newell (*132*) described two stages as "hard ripe shipping" and "advanced." Blake and Davidson (*20*) distinguished five stages as follows: "Long distance shipping," "nearby shipping," "hard ripe," "firm ripe," and "soft ripe." Davies, Boyes, and De Villiers (*50*), Kelley and McMunn (*123*), and Haller[5] divided experimental lots of peaches into three classes described as "least mature," "medium or intermediate maturity," and "most mature." Designations of "immature," "semi-mature," and "mature" were used by Tindale, Huelin, and Trout (*207*); "green ripe," "firm ripe," and "tree ripe" by Dorsey and McMunn (*60*); "hard ripe," "firm ripe," and "tree ripe" by Jorgensen and Ornelas (*121*); and "hard green," "firm turning," and "soft yellow" or "nearly tree ripe" by Reyneke (*183*). Fisher and Britton (*66*) designated four stages as "immature," "medium mature," "mature," and "tree ripe."

Standardization of the terms used to designate the different stages of maturity would be desirable. The use of "ripe" as "hard

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[5] Unpublished data.

ripe" or "shipping ripe" in connection with maturity designations is undesirable.

The following maturity terms are suggested:

Immature.—Hard green peaches that require more than 10 days at room temperature (65° to 80° F.) to ripen, and that finally ripen to poor dessert quality, usually with much shriveling.

Hard mature.—Hard peaches that ripen in 5 to 10 days at room temperature to fair to good quality.

Firm mature.—Texture still generally firm with possibly very slight softening at the suture or opposite the suture. Ripening in 2 to 5 days at room temperature, generally to good or to very good quality.

Soft mature.—Considerable softening at the suture within 1 to 2 days of being full ripe.

Tree ripe.—Entire peach soft and fully ripe.

Peaches that have been designated as "shipping ripe" would probably be included in both the hard mature and the firm mature stages defined above. The hard mature would probably predominate during the early part of the harvest season and the firm mature late in the harvest season. Peaches that have been designated "tree ripe" in some publications apparently were in the condition described above as soft mature or firm mature.

Definitions and descriptions of ripening terms are given on page 37.

SIZE

A number of investigators have stressed the desirability of leaving peaches on the trees as long as possible in order to obtain the maximum volume. Blake and others (*21*) in New Jersey showed that the increase in volume of Elberta peaches near the harvest period was generally 2 to 4 percent per day and was as high as 6 to 7 percent in some instances. Allen (*5*), in California, found the increase in volume per day of five varieties to range from 2 to 5 percent. In Utah, the volume increase was given as 2 to 4 percent per day by Coe (*45*), who further stated that the volume increase from the first commercial picking to optimum picking was 15 percent, and from a hard condition to a firm condition about 25 percent. McMunn and Dorsey (*136*) reported a similar increase for Illinois of 20 to 25 percent during the 7 days preceding optimum shipping maturity. A somewhat wider range of 20- to 40-percent increase in volume was reported for Canada by Fisher and Britton (*66*) during the week preceding optimum maturity. Upshall and Van Haarlem (*212*) measured the volume increase during four seasons in Ontario, Canada. They found that in the 7 days preceding optimum maturity, the volume increase was 16, 29, and 35 percent, respectively, for Elberta, Veteran, and Golden Jubilee. Upshall (*210*) gives similar increases of 18, 20, 41, and 23 percent for Elberta, Veteran, Golden Jubilee, and South Haven.

Increase in size as measured by weight of the fruit has been reported as follows: In Washington the increase was 35 and 42.5 percent, respectively, for J. H. Hale and Elberta during the 13 or 14 days between shipping and canning stages of maturity, according to Allmendinger, Overley, and Overholser (*11*). A similar rate of about 10 percent per 3 days was reported by Neubert, Veldhuis, and Clore (*168*). In Illinois, Halehaven peaches increased 34 percent in weight between commercial maturity and a firm to soft stage of maturity, according to Lott (*134*). Data presented by Jorgensen and Ornelas (*121*) indicated a weight increase of 58 percent during the 9 days when the fruit changes from a hard to a soft stage of maturity.

Perhaps a more practical measure of size is diameter. This is the measure used to indicate the size of peaches packed in bulk containers such as bushel baskets. Measurements of this type by Dorsey (*58*), in Illinois, showed that fruit $2\frac{1}{4}$ inches or more in diameter increased from about 47 percent of the crop when picking started to 93 percent when picking was delayed 7 or 8 days. Dorsey indicated that 340 peaches $1\frac{3}{4}$ inches in diameter are required to fill a bushel basket, and that only 110 are required when diameters are $2\frac{3}{4}$ to 3 inches. In the intermediate sizes the number of fruits required per bushel are: 2 to $2\frac{1}{4}$ inches, 250; $2\frac{1}{4}$ to $2\frac{1}{2}$ inches, 195; $2\frac{1}{2}$ to $2\frac{3}{4}$ inches, 140.

There appears to be ample evidence of rapid increase in the volume and weight of peaches during the harvest period. The increase varies greatly with variety and probably with other factors. Blake and others (*21*) stated that the size of the fruit depended more on the size of the crop than on the vigor of the trees as affected by nitrogen fertilization. They further indicated that cloudy and wet periods are often followed by an increase in the rate of fruit growth. On the other hand. Lott (*133*) observed that heavy nitrogen fertilization increased the yield of peaches and the size of the individual fruits. Williams and Veerhoff (*225*) observed that soil application of either $\frac{1}{8}$ or $\frac{1}{4}$ pound of borax per tree resulted in appreciably larger fruit. The trees were in a sandy soil that probably was deficient in boron.

The results show that, in general, a material increase in production would be one of the benefits from picking at an advanced stage of maturity. Thus, Allmendinger, Overley, and Overholser (*11*) indicated that a price of $80 to $84 per ton for fresh peaches picked at the shipping stage of maturity would be equivalent to a price of $60 per ton for the larger crop picked at the (more mature) canning stage of maturity.

After being picked, peaches no longer increase in size, and there may actually be a slight shrinkage due to loss of moisture. In a shipment of Hiley peaches from Georgia in vented half-bushel baskets, Mallison and Bratley (*142*) found that the peaches shrank $\frac{1}{32}$ of an inch in least diameter during transit. When peaches are closely graded, this much shrinkage may be sufficient to cause many of the fruits to become smaller than the minimum size allowed for the grade. Mallison and Bratley also found that

shrinkage was greater in the top layer of the car than in the bottom layer. The inspection service has taken this into account; inspectors now allow the fruit to be 1/16 of an inch undersize at the terminal markets without reversing shipping-point certificates.

SHAPE

As increase in size during the final swell is greater in some directions than in others, the developing fruit changes in shape. Shape is generally reported as the ratio of length to suture diameter to cheek diameter. Blake and others (*21*) found these ratios in Elberta to change from 1 : 0.91 : 0.81 at 115 days from bloom to 1 : 0.96 : 0.91 at maturity. Fisher and Britton (*66*) stated that the diameter across the cheeks increased more rapidly than across the suture. At maturity the ratio of cheek diameter to suture diameter was 0.99 to 1.02 for three varieties.

GROUND COLOR OF SKIN

As peaches approach maturity, the leaf-green ground color changes to a lighter shade of green. Simultaneously, a gradual yellowing, starting on the sides exposed to the light, takes place. As the peaches become ripe, a deep orange yellow develops on yellow-fleshed varieties, and yellowish white develops on white-fleshed varieties. Changes in ground color continue during ripening after the fruit has been picked. Somewhat deeper shades of yellow or orange usually develop in fruit picked at an advanced stage of maturity. The rate of change is proportional to the rate of ripening and is more rapid at the higher temperatures (*5*).

Coe (*45*) and Wilson and Upshall (*230*) presented color charts for use with peaches. Some of the shades as reproduced on Coe's chart do not seem to match the shades of yellow found on peaches. The standard USDA color chart for apples and pears has also been used and, although the shades of color do not very well match the shades found on peaches, it has been possible to determine the shades fairly accurately by them.

Blake and others (*21*), in New Jersey, and Coe (*45*), in Utah, have noted that fruit from trees in a high state of vigor associated with high nitrogen fertilization were slower to turn yellow and were greener in color at a given stage of maturity than fruit from trees in a moderate or low state of vigor.

Most of the ground-color studies have been made in connection with maturity investigations and will be presented later in that connection.

RED COLOR OF SKIN

As fruit matures and ripens on the tree there is a fairly rapid development of red color, which varies greatly with variety and exposure to light. Trees in a high state of vigor (high nitrogen) usually produce fruit of poor color (*21*). This is probably caused

in part by shading of the fruit. Red color was reduced by borax applications to trees growing in a sandy soil (*225*). Treating picked peaches with methyl bromide (*42*) greatly increased red-color development, but the treatment was not practical as it also impaired flavor. Red-color development normally ceases after the fruit is picked (*5*).

FLESH COLOR

Along with changes in the ground color of the skin of peaches, there is a gradual change in color of the flesh, from green to yellow or white. There is also a reddening at the pit surface of many varieties, with rays of red extending into the flesh during maturation and ripening. Willison (*228*) observed that flesh-color changes were usually correlated with flesh firmness, but that in some seasons the fruit matured with little or no color change in the flesh. Because of the difficulty in determining flesh color, relatively few determinations have been made.

PIT COLOR

In immature peaches the surface color of the pits is a light whitish brown. As the fruit matures and ripens the color changes to deep red and finally to dark brown. There seems to be very little published evidence on the rate of this change or its relation to other factors.

FIRMNESS AND TEXTURE

Firmness of the fruit has usually been determined by means of a pressure tester. Haller (*79*) has reviewed the literature previous to 1941 on the use of pressure testers with peaches and other fruits. It is noted that the methods of testing the firmness of peaches have varied greatly in number of tests per peach, points at which the tests were made, size of plungers, and whether the tests were made on the pared or unpared surface. This lack of uniformity makes it impossible to compare results obtained by the different methods.

Haller (*79*) suggested that for the sake of uniformity a standard method of testing be adopted. The method suggested involved use of a tester equipped with a plunger 5/16 inch in diameter, and a test to be made on each pared cheek. Additional data and suggestions on methods of pressure-testing peaches have since been presented. Comparison of 7/16- and 5/16-inch plunger tips have been made by Willison (*228*), Fisher, Britton, and O'Reilly (*67*), and Veldhuis and Neubert (*218*). Willison first used a plunger tip of 7/16 inch but later changed to one of 5/16 inch. Fisher, Britton, and O'Reilly (*67*) reported that readings on the unpared cheeks of seven varieties averaged 4.0 to 10.6 pounds higher on the different varieties when a plunger point of 7/16 inch was used than when one of 5/16 inch was used. In their studies they used the results obtained with the 5/16-inch plunger point. Veldhuis and

Neubert (*218*) also started using a plunger tip of 7/16 inch but switched to one of 5/16 inch, except for soft fruit with which the 5/16-inch plunger did not offer sufficient resistance to penetration to register on the scales. Upshall and Van Haarlem (*212*) and Jorgensen and Ornelas (*121*), who have published results with pressure testers since 1940, have also used plunger points of 5/16 inch. This size seems to have been rather uniformly adopted for use with peaches.

Whether the tests should be made on the unpared flesh or through the skin has not been so well standardized. Willison (*228*) showed a high correlation between tests made on the pared cheeks of peaches with those made through the skin. (Those made through the skin averaged 5 to 6 pounds higher.) Willison preferred tests through the skin because the higher readings made tests on soft fruit possible. Tests through the skin are easier to make, as no peeling is necessary—and they include toughness of the skin, which may be a factor in carrying quality. Upshall and Van Haarlem (*212*) found somewhat smaller differences of 3.5 to 4.5 pounds between tests made on pared and unpared cheeks of peaches, but they used results from the pared cheeks. Smith (*194, 195*) made tests through the skin, as did Fisher, Britton, and O'Reilly (*67*) and Jorgensen and Ornelas (*121*). Veldhuis and Neubert (*218*) made tests on the pared flesh.

Whether tests should be made through the skin seems to depend on the purpose of the tests. If the tests are made for the purpose of comparing the probable shipping quality of different varieties or seedlings, toughness of the skin would be of interest. Skin toughness would be indicated by the difference between pressure-test readings of pared and unpared fruit. On the other hand, if the tests are made to measure the maturity or ripeness of the fruit, such information would be indicated by the firmness of the flesh. To test through the skin in the latter case would introduce a possible source of error. Since most pressure-test determinations have been used to indicate maturity or ripeness, it would seem desirable that the tests be made on the pared flesh—even though this is somewhat less convenient. This is the standard procedure used with apples and pears, for which the same principles apply.

In most of the recent investigations (since 1940), pressure-test determinations have been made on the cheeks of the fruit (Smith (*194, 195*), Willison (*228*), Fisher, Britton, and O'Reilly (*67*), Upshall and Van Haarlem (*212*), and Jorgensen and Ornelas (*121*)). However, Haller (*78*) noted that tests on the suture sometimes indicated differences between lots when tests on the cheeks did not. He suggested that tests on the suture might give a more sensitive index of maturity than tests on the cheeks. Veldhuis and Neubert (*218*) made tests on the suture and opposite the suture as well as on the cheeks. Since peaches usually soften first at the suture or opposite the suture, pressure-test determinations at these points are likely to be of value in addition to tests on the cheeks.

Pressure-test determinations and observations have shown a softening of the fruit during maturation and ripening—from a hard, tough, woody condition (pressure-test readings of more than 20 pounds) when immature to a very soft, juicy condition (pressure-test readings of less than 3 pounds) when fully ripe. The pressure-test readings at different stages of maturity and ripeness have varied with the size of the plunger point used and the method of testing. In general, pressure-test readings have been made in connection with the determination of picking maturity. They will be discussed further under that subject.

Degman and Weinberger (*54*) found no consistent effect on the firmness of peaches from use of various forms of either nitrogen or potash fertilizers in the orchards.

COMPOSITION

Studies of chemical changes in peaches have been concerned primarily with total solids, soluble solids, sugars, acids, vitamins, and pectic materials.

TOTAL SOLIDS

Percentage of total solids, or dry weight, did not change appreciably during maturation or ripening, according to Neubert and others (*165, 166*). It would seem likely that the percentage of total solids might vary, depending on weather conditions. With wet humid weather just previous to or during maturation, the proportion of solids to moisture would probably decrease. On the other hand, a period of wet weather followed by a dry period would probably result in an increase in percentage of solids. That seasonal conditions materially influence the percentage of dry weight was observed by Haller and Harding (*82*). They found the percentage of dry weight at maturity in four varieties to be 11 to 13.3 percent in one season and 14.5 to 16 percent in another season. Thinning also increases the percentage of total solids, as reported by Moon and others (*160*).

SOLUBLE SOLIDS

Soluble solids have been determined at different stages of maturity, both in fruit of the same picking and in fruit picked at different times. The results are conflicting in that Neubert and others (*165*) and Reyneke (*183*) found no appreciable change during maturation, whereas Allen (*5*), Huelin, Tindale, and Trout (*115*), Fisher and Britton (*66*), and Fisher, Britton, and O'Reilly (*67*) reported a slight increase during maturation. Jorgensen and Ornelas (*121*) reported a slight decrease at the approach of maturity, followed by an increase. From these results it would seem that there is a tendency for soluble solids to increase slightly during maturation, but that under some conditions the increase will be insignificant or lacking. Percentage of soluble solids in different varieties of peaches grown under different conditions varied in the above citations from 10.5 to 14.3. Van Blaricom and

Musser (*215*) reported that soluble solids varied from 8.6 to 13.4 percent in ripe fruit in 45 varieties. Thinning increased the percentage of soluble solids, according to reports by Moon and others (*160*). No appreciable change in percentage of soluble solids has been found during ripening after harvest (*5, 165*).

TOTAL SUGARS

Percentage of total sugars varies considerably at fruit maturity. The percentages ranged from 6.3 to 10 in four varieties tested by Haller and Harding (*82*). The sugars constitute a major part of the soluble solids. As with soluble solids, there has been no consistent change in total sugars in relation to fruit maturity. Neubert and others (*165*) found no appreciable change during maturation, whereas Allen (*5*), Lott (*134*), and Upshall (*211*) reported slight increases. The concentration of reducing sugars was found by Blake and Davidson (*20*) to remain rather constant at 2.0 to 2.5 percent during maturation, but a gradual increase in sucrose was reported by Allen (*5*), Blake and Davidson (*20*), and Lott (*134*). An increase in the proportion of fructose to glucose was reported in Elberta peaches during maturation by Kokin (*126*). Sugars were found to be higher in thinned than in unthinned peaches by Moon and others (*160*). No appreciable change in the concentration of the sugars was observed during ripening after harvest by Blake and Davidson (*20*), Lott (*134*), and Neubert and others (*165*).

TOTAL TITRATABLE ACIDITY

Total titratable acidity in peaches has ranged from about 0.5 to 1.0 (Allen (*5*), Haller and Harding (*82*), and Neubert and others (*165*)), depending on variety, locality, thinning (Moon and others (*160*)), and other factors. Total acidity has been found to decrease consistently with advance in picking maturity (Allen (*5*), Blake and Davidson (*20*), Huelin, Tindale, and Trout (*115*), Lott (*134*), Neubert and others (*165*), Upshall (*211*), and Reyneke (*183*)). Allen (*5*) found total acidity to decrease particularly fast as the fruit approached tree ripeness. Neubert and others (*165*) found that total acidity remained nearly constant after the fruit reached a stage of maturity at which it would ripen in 6 to 7 days. Lott (*134*) reported that loss in total acidity continued during ripening after harvest. Haller and Harding (*82*) observed that the loss was particularly great at unfavorable storage temperatures (36° to 50° F.), at which breakdown and loss of flavor were particularly evident.

The ratio of soluble solids to acids has been used as an index of maturity for some fruits, such as citrus, grapes, and cantaloups. Reyneke (*183*) found the ratio in peaches to increase with maturity from 13.8 to 19.9. This increase was due principally to the decrease in acidity. Not much evidence is available along this line, but from the variability reported for soluble solids and acids, it is likely that the ratio of soluble solids to acids would also vary greatly.

ASCORBIC ACID

Ascorbic acid (vitamin C) content of peaches is of interest primarily with respect to the nutritional value of the fruit. Schroder, Satterfield, and Holmes (*190*) reported that the ascorbic acid content of eight varieties of peaches grown in North Carolina ranged from 3.8 milligrams (mg.) per kilogram (kg.) for Augbert to 12.8 mg. per kg. for Hiley, and that Elberta peaches were intermediate, with 5.24 mg. per kg. The ascorbic acid content remained practically constant during maturation and ripening, according to Neubert and others (*165*). In general, the results indicate that there is great variability among varieties and that peaches are relatively low in ascorbic acid content.

CAROTENE AND CAROTENOIDS

Carotene and carotenoids (vitamin A) are also of interest from the standpoint of nutritional value of the fruit. The percentages of these constituents were found by Neubert and others (*165*) to increase in peaches until the fruit reached a stage of maturity at which it would ripen in about 9 days. The percentages remained practically constant during further maturation and ripening. Reynolds and Cooper (*14*), at the Arkansas Agricultural Experiment Station, found that the carotene content varied from 20 to 500 micrograms (μg.) per 100 grams (gm.) in 17 varieties of peaches. Crawford's Early and Wilma were highest. Elbertas contained 290 μg., and Rochester, Halehaven, and Golden Jubilee had about the same amount. There was no significant loss for canned peaches during canning or during the normal storage period.

TANNINS

Tannins are associated with astringency and bitterness in peaches and thus affect the dessert quality. Neubert and others (*165*) found that tannins decreased until the fruit reached a stage of maturity at which it would ripen in 6 to 7 days. Past this stage the tannins remained fairly constant. This agrees generally with the observation that astringency and bitterness in the fruit decrease with advance in maturity.

PECTIC MATERIALS

Softening of peaches is associated with the transformation of the insoluble protopectin to soluble pectin (*13, 67, 82*). Appleman and Conrad (*13*) reported that total pectic material (protopectin plus pectin) remained practically constant at all stages of maturity and ripeness, so that a determination solely of soluble pectin constitutes a good measure of pectic changes. Appleman and Conrad (*13*) and Fisher, Britton, and O'Reilly (*67*) found that increase in pectin is relatively slight during maturation; but they and Haller and Harding (*82*) also found that it increases very rapidly during ripening at room temperature. Fisher, Britton, and O'Reilly (*67*) and Haller and Harding (*82*) reported that the rate of increase in pectin and the rate of

softening are proportionately reduced at cold-storage temperatures.

JUICINESS

Juiciness is probably associated in part with changes in the pectic materials. Reyneke (*183*) observed that peaches on the tree are juicy in early maturity (when still green), become nearly juiceless at intermediate maturity, and are again juicy when tree ripe. Fruit picked when green and juicy and held at room temperature ripened to the juiceless condition in about 24 hours and became juicy again in another 24 hours. Fruit picked at intermediate maturity (juiceless condition) and held at room temperature ripened to a juicy condition in 24 hours. Reyneke (*183*) stated that peaches placed in cold storage in the juiceless condition lost their ability to become juicy and ripened to a woolly (mealy) condition.

HARVESTING

DETERMINATION OF MATURITY

Maturation among peaches is more uneven than with some other fruits, such as apples. Even on the same tree some peaches reach maturity while others are still distinctly immature. Consequently, several pickings are usually made, and the pickers must be able to distinguish easily and quickly mature fruit from immature fruit. Mature peaches are distinguished primarily by the ground color, and possibly to some extent by size and shape. Although an easily recognizable change, such as a change in color, must be used as a guide for picking, any of the physical and chemical changes associated with maturation might be used to establish the proper shade of ground color to be used as a standard for picking.

TIME FROM BLOOM

Time from bloom has been used as a maturity index for apples. This might be useful with peaches also in predicting the approximate time at which picking of the more mature fruit might start. It would not take the place of other maturity indexes, as some means of distinguishing between mature and immature fruit at any particular picking would still be necessary.

The period from bloom to harvest for a number of peach varieties as grown in different States is given in table 1. Figures for the different States are not directly comparable, as the point during the harvest season used as a basis of maturity varied from the date of start of first picking in Georgia to later than commercial maturity in New York.

The first extensive report on the period from bloom to harvest (height of the harvest) was by Blake (*19*) for New Jersey. There was considerable variation in this period within varieties during different seasons. Blake observed that the short periods from

TABLE 1.—*Time from bloom to harvest for 22 varieties of peaches, as grown in different States*

Variety	Time from bloom to harvest[1] when grown in—							
	Georgia (*222*)[2]		Delaware (*55*)[2]		New Jersey (*19*)[2]		New York (*208*)[2]	
	Range	Average	Range	Average	Range	Average	Range	Average
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
Mayflower	49–56	53			66–77			
Greensboro					86–101		82–102	91
Erly-Red-Fre			92–94	93				
Alton					100–108			
Carman					101–116		103–115	113
Rochester							103–118	104
Cumberland			106–107	106				
Golden Jubilee			107	107				
Triogem			112–113	112				
Mountain Rose					109–133			
Reeves					111–136			
Vedette			113–117	115				
Valiant			118–119	118				
Early Crawford							118–130	118
Belle (Belle of Georgia)					117–135		120–132	122
Halehaven			121	121				
Early Hiley		92						
Hiley		99					122–134	126
Early Elberta			129–131	130				
Elberta[3]	104–124	113	135–138	136	123–144	130	126–138	128
Late Crawford							128–136	133
J. H. Hale			134	134				

[1] Harvest dates selected as follows: Georgia, date of start of first picking; Delaware, main picking for local market; New Jersey, height of commercial picking; New York, later than commercial maturity.

[2] Italic numbers in parentheses after State names refer to Literature Cited, p. 92.

[3] Time from bloom to canning stage of maturity for Elberta grown in Washington (*168*) ranged from 140 to 146 days, with an average of 142 days.

bloom to harvest were usually associated with late blooms and warm temperatures during the early part of the growing season, and that the long periods were associated with early blooms and cool temperatures during the early part of the growing season. Tukey (*208*), on the other hand, states that in New York the periods were not generally longer in seasons of early bloom.

Weinberger (*222*) determined the correlation between the length of the period from bloom to harvest and the average maximum and minimum temperatures for different periods following bloom. The highest correlation (—0.93) was with the average maximum temperature during the 50 days following bloom. He concluded that for Elberta peaches at Fort Valley, Ga., an adjustment in the average period should be made by adding or subtracting 1 day from this period for each 1.86° F. the average maximum temperature during the 50 days following bloom was below or above the normal for this period. Although factors other than temperature may affect the length of the fruit-development period, by correcting for early-season temperature effects, more than half the variability between the expected and observed date of maturity was eliminated.

The periods from bloom to maturity given in table 1 are much shorter for southern Georgia than for the other (northern) States. This is partly due to the fact that the period for Georgia was to the beginning of harvest, whereas in New Jersey it was to the height of harvest, and in New York and Washington to late maturity. However, the shorter period for southern Georgia was probably due primarily to insufficient cold to break the rest period in this section. This would delay the bloom so that the 50 days following bloom usually would be during a warmer period, and consequently the period from bloom to harvest would be shorter because of the adjustment for temperature.

Williams and Veerhoff (*225*) observed that borax application to peach trees growing in a sandy soil delayed bloom but hastened maturity. This would therefore appreciably shorten the period from bloom to maturity.

As a further check on the probable date of harvest, Weinberger [6] has suggested using a period based on the stage of embryo development. He has observed that early maturity or the beginning of harvest is 34±2 days after the embryos average ⅛ inch in length.

SIZE

Although peaches enlarge rapidly during the final swell just previous to and during maturation, this factor cannot be used as an index of maturity; the peaches vary greatly in size at maturity, depending on other factors, such as degree of thinning, tree vigor, and weather conditions. In this connection, Neubert, Veldhuis, and Clore (*168*) observed that peaches from low-vigor

[6] J. H. Weinberger. Bureau of Plant Industry, Soils, and Agricultural Engineering, Fort Valley, Ga., Field Station. Unpublished data.

trees were smaller and appeared more mature than those from high-vigor trees, but that the respective fruits ripened in about the same length of time. Haller [7] divided tree-run peaches picked from the same trees at the same time into different degrees of maturity based on ground color. Peaches of advance maturity averaged appreciably larger than those of the less mature stages. However, there was considerable overlapping of size among the samples of different degrees of maturity.

SHAPE

During the final swell there is a tendency for the fruit to increase in diameter across the cheeks more rapidly than it does across the suture. The ratio of cheek diameter to suture diameter in three varieties at maturity, computed from data presented by Fisher and Britton (*66*), averaged 0.99 to 1.02. Fisher and Britton (*29, 66*) recommended use of this ratio as an index of maturity. However, their data do not seem to justify this recommendation, as the change in this ratio during maturation was too gradual and inconsistent. In the case of the Rochester variety, for example, fruit at optimum maturity from one tree had a ratio of 0.99, but the ratio for fruit from the same tree had been the same 1 week earlier (when it was rated immature), and fruit from another tree had been 0.99 2 weeks earlier. Similar inconsistencies occurred in the other varieties. That shape was unreliable as an index of maturity had been noted earlier by Morris (*162*), who observed that peaches may soften without filling out under unfavorable growing conditions. Willison [8] also listed form among the indexes to maturity of peaches that were less reliable than the pressure-test or ground-color indexes.

RED COLOR OF SKIN

The development of red color, or blush, is very desirable from the standpoint of attractiveness of the fruit. Although red color generally increases during maturation, it is dependent on other factors, such as exposure to light, and is therefore unreliable as an index of maturity. Early maturity may be reached in many peaches without any red showing. In commercial practice red color is probably used in picking the fruit, as the pickers usually look for a break in color and do not seem to make a distinction between the development of red color and changes in ground color. The red color will be dull when the underlying ground color is green, and a brighter red when the underlying ground color is yellow. Thus, a bright-red color may be an indirect indication of a break in ground color, particularly as the first break in ground color usually occurs on the exposed side and may be covered by the red color. There seem to be no recent data on the value of red color as an index of maturity, but general observations indicate that it is not a very reliable index.

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[7] Unpublished data.

[8] WILLISON, R. S. PROBLEMS RELATING TO THE MATURITY, TRANSPORTATION AND STORAGE OF PEACHES. 4 pp. [Saint Catharines, Ontario.] [1942.] [Processed.]

GROUND COLOR OF SKIN

As peaches approach maturity they are a light-green color of about the same shade over the entire surface. A definite break in color toward yellow usually occurs first in a small area on the exposed side of the peach. At this time the remainder of the peach may show no appreciable change. The yellowing area gradually deepens in color and enlarges until the entire fruit becomes yellowish. In picking certain varieties, such as Elberta, particularly early in the harvest period, the pickers may harvest all fruit showing this definite break in ground color in only a small area. Therefore, in determining ground color for the purpose of studying its use as an index of maturity, it would seem to be important to determine the color at the point on the fruit that first shows a change in color. Whether ground color was determined at the least advanced, most advanced, or an intermediate portion of the fruit is not indicated in most reports. Yet widely different results might be obtained, depending on which portion was used.

Magness and Allen (*140*) described the color at maturity of four varieties of peaches grown in California as follows: Greenish yellow in the case of Triumph and Early Crawford; yellowish green for Elberta; and nearly full yellow for Tuscan. For Illinois, Lloyd and Newell (*132*) suggested picking Elberta peaches at a lemon to yellow stage. Upshall (*211*), also, showed that Elberta peaches at optimum maturity are mostly yellow and stated that there is no better index of maturity for orchard use than the disappearance of the green from the ground color.

Blake and others (*21*), Morris (*162*), Coe (*45*), Willison (*228*), Neubert, Veldhuis, and Clore (*168*), and Huelin and Tindale (*114*) have questioned the usefulness of ground color as a direct index of maturity because it differs at the same stage of maturity in peaches from trees of different growth status and with seasonal conditions. Peaches from trees of low vigor (high carbohydrate) were more yellow at the same firmness than those from trees in a high state of vigor (high nitrogen), according to Blake and others (*21*), Coe (*45*), Morris (*162*), and Neubert, Veldhuis, and Clore (*168*). Differences in ground color have also been attributed to weather or seasonal conditions (Morris (*162*), Coe (*45*), Willison (*228*)), although the exact relationship has not been indicated. Morris (*162*) stated that the color at maturity also varies with the size of the crop. Because the color varied with these other factors, Morris (*162*) concluded that it is not possible to designate a definite color standard for maturity.

Coe (*45*) presented a color chart for peaches showing six colors. He recognized that the color varied with the growth status of the tree and he recommended use of different color standards, depending on the growth status. According to Coe, Elberta peaches from highly vigorous trees at picking should be greenish yellow to sulfur yellow; from moderately vigorous trees, sulfur yellow to between sulfur yellow and amber yellow; and from weakly vigorous trees, yellow to amber yellow. J. H. Hale at maturity should be generally

sulfur yellow to amber yellow. Coe considered color and pressure test as the most accurate indexes of maturity. He states that color indicated the potential dessert quality and attractiveness, and the pressure test indicated carrying quality.

Willison (*228*) observed that in some seasons peaches may be ready to pick before any appreciable yellowing takes place. In that case ground color could not be used as an index of maturity. Willison considered color less reliable than the pressure test as an index of maturity. Fisher, Britton, and O'Reilly (*67*) found that ground color varied slightly between seasons, but that in each season the mature peaches showed a warmer shade of yellow than immature peaches picked at the same time. However, Rochester and J. H. Hale peaches had a yellowish skin even when immature. These writers do not give color standards for picking.

Veldhuis and Neubert (*218*) gave the maturity standard for Elberta, based on two seasons' work, as deeper yellow than number 4 (on the apple-pear color chart) at canning maturity, and number 3 or less at shipping maturity. Wilson and Upshall (*230*) presented a color chart for peaches of light green (number 1) to dark yellow (number 3) corresponding to 19J1 and 10J2, respectively, in Maerz and Paul (*139*). Elberta, Veteran, and Jubilee (Golden Jubilee), picked before reaching the number 1 color, were immature and were inferior in appearance and quality. Those picked at a color between numbers 1 and 2 were of satisfactory maturity. Those picked at a color between numbers 2 and 3 were too soft and were subject to excessive bruising.

Allen (*9*) recommended picking peaches when the skin and flesh show considerable development of color in most varieties. He also recommended that J. H. Hale should be full yellow color.

In general, it would seem that ground color is influenced by too many factors other than maturity to be used directly as an index of maturity. However, the principal factor influencing color, other than maturity, seems to be the growth status of the tree. It may be that allowance or correction can be made for this so that ground color can be used as an index of maturity in conjunction with other tests. At any rate, ground color remains the principal guide to picking, even though the exact color to be used may have to be established by scientific tests.

COLOR OF FLESH

Along with the change in ground color of the skin, there is a yellowing of the flesh. Britton (*29*) has suggested that this yellowing might be useful as an index of maturity in some varieties, as he observed that the flesh color may change before the ground color of the skin. Willison (*228*) found that changes in flesh color were usually correlated with softening (pressure test) but that in some seasons peaches softened and became mature before any appreciable change either in flesh color or ground color took place. Fisher, Britton, and O'Reilly (*67*) observed that the flesh color at maturity varied in different seasons, although in each season the flesh of mature peaches showed warmer shades of

yellow than immature peaches. As with skin color, the flesh of Rochester and J. H. Hale peaches was yellowish before the fruit was mature. Allen (*9*) recommended picking when the flesh and skin of peaches both show considerable yellowing. For canning, Van Blaricom and Musser (*215*) recommended picking when the flesh color starts to turn, but while the flesh is still firm.

Although flesh color has been suggested as an index of maturity for peaches, no exact standards have been established for this. Flesh color as an index of maturity is subject to the same criticisms as ground color of the skin. In addition, flesh color can only be used indirectly to establish the proper ground-color standard for picking. There seems to be no advantage in using flesh color instead of ground color of the skin.

COLOR OF PIT

Relatively few data are available on the relation of changes in pit color to maturity. Recently, Neubert and others (*165, 166*) reported that browning of the pit was a specific and constant index of maturity during two seasons in Washington. They stated that brown color on at least 5 percent of the pit area was necessary for good quality at picking. Haller [9] was unable to confirm this under eastern conditions. In one season of work in Georgia and Pennsylvania, he found that pit browning occurred in a large proportion of peaches in some lots before they were mature, and that in others pit browning did not occur until some time after the fruit was mature. Additional studies are needed to evaluate the reliability of this index.

PIT FREEDOM

In freestone varieties of peaches the pit does not become free until the fruit approaches maturity. This condition has been suggested as a possible index of maturity. Few data were found in the recent literature relative to its reliability, but Coe (*45*) found the "freedom of pit" test was not a reliable index of maturity, and Willison [10] lists freedom of pit among factors that were less reliable than pressure test or even ground color of the skin.

SPLIT PIT

Peaches with split pits are culls, but where the split is not severe it frequently is not possible to distinguish such fruit from sound fruit. Severe split pit is generally associated with rapid ripening of the fruit, but Neubert and others (*165, 166*) observed no relation of split pit to maturity.

PRESSURE TEST (FIRMNESS)

Many investigations have been conducted on the possibility of using the pressure test as an index of maturity by which a color or other guides for picking could be established. The conclusions drawn from these tests have been almost as varied as the methods of making the tests.

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[9] Unpublished data.
[10] See footnote 8, p. 15.

Magness and Allen (*140*) were the first to report on the use of the pressure tester with peaches. They concluded that firmness of peaches (as determined by pressure test) was more closely associated with shipping quality and potential dessert quality than other tests. They gave a pressure-test range for four varieties for shipment from California. Morris (*162*), also, indicated that the pressure tester could be used to determine the color standard for picking peaches. He used this method with Washington-grown peaches—but he did not recommend a specific pressure-test range for picking.

Under eastern conditions, Blake and others (*21*) indicated that the pressure tester could be used as an index of maturity, provided different standards were used that were dependent on the growth status of the trees. Blake and Davidson (*20*) recommended rather narrow ranges in pressure test for five different degrees of maturity, depending on the amount of handling and the distance the fruit is to be shipped. Coe (*45*) observed that "while there was considerable variation in pressure tests and ground color under different conditions and seasons, these indexes of maturity appear to be more useful and accurate than any other tested." For picking Elberta peaches he recommended pressure-test ranges that depend on the growth status of the trees. On the other hand, Britton (*29*) stated that the pressure test at maturity could not be standardized, as the firmness varied with weather, culture, size of crop, and other factors. Mallison, Bratley, and Wiant (*143*) also noted an inconsistency in that one lot of Hiley peaches tested softer than another, even though they seemed less mature. However, Willison [11] observed that as carrying quality depends largely on firmness, the pressure test provides one of the most valuable indications of maturity. He gave ranges in pressure test for different degrees of maturity and stated that the pressure test gave a reasonably accurate indication of the passing of the maturity point.

Fisher, Britton, and O'Reilly (*67*) determined the firmness of four varieties at maturity in two seasons. They found that the pressure test of the varieties at maturity was not consistent in the two seasons. Upshall and Van Haarlem (*212*) considered the pressure test the best single index of maturity in peaches. Haller [12] divided several tree-run pickings of Elberta peaches into mature and immature lots. In many instances there was very little difference in firmness between the mature and immature fruit, and there was considerable overlapping of the pressure-test readings. Furthermore, Haller observed that in some cases the mature fruits of an early picking were firmer than immature fruits of a later picking. Such inconsistencies would make the pressure test of questionable value. Softening was more rapid at the suture than on the cheeks. For this reason it seems likely that tests at the suture or opposite the suture might provide a more sensitive index of maturity than tests on the cheeks.

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[11] See footnote 8, p. 15.

[12] Unpublished data.

TABLE 2.—*Firmness (indicated by pressure test) of Elberta peaches*[1] *at different stages of maturity and from different sources*

Source, authority,[2] and date of report	Tests made on—	Stage of maturity	Pressure test with plunger diameter of— 3/16 inch	5/16 inch	7/16 inch
			Pounds	*Pounds*	*Pounds*
California, (*140*), 1926	Pared cheeks	Shipping[3]		12.0 to 16.0	
New Jersey, (*21*), 1931	Unpared cheeks	Optimum[3 4]	8.0 to 9.0		
Utah, (*45*), 1933	do	Shipping[3 5]		15.0 to 18.0	
		do[3 4]		12.0 to 18.0	
		do[3 6]		12.0 to 20.0	
New Jersey, (*20*), 1936	do	Long-distance shipping[3]	8.5 to 10.0	17.0 to 20.0	
		Nearby shipping[3]	7.5 to 8.5	15.0 to 17.0	
		Local market[3]	6.0 to 7.0	12.0 to 14.0	
		Roadside market[3]	4.0 to 5.5	8.0 to 11.0	
		Soft ripe	3.0 or less	6.0 or less	
Virginia and Maryland, (*82*), 1939.	Pared cheeks	Shipping[3]		11.0 to 14.0	
Maryland, (*78*), 1939	do	do		15.9	
	Pared suture	do		12.5	
Georgia, (*143*), 1939	Pared cheeks	Hard		18.2 and 20.2	
		Firm		16.1 and 17.2	
Washington, (*194*), 1940	Unpared cheeks	Optimum shipping		10.0 to 18.0	
		Advanced shipping		5.0 to 11.0	
Ontario, Canada, (*228*), 1941	do	Early		19.0 to 20.0	
Washington, (*72*), 1941	Pared cheeks	Shipping		11.6 and 14.2	
Ontario, Canada,[7] 1942	Unpared cheeks	Distant shipping[3]		16.0 to 18.0	
		Nearby shipping[3]		12.0 to 14.0	
		Local market[3]		8.0 to 10.0	
		Roadside market		4.0 to 6.0	
British Columbia, Canada, (*67*), 1943.	do	Early		16.7 and 18.8	25.3

Washington, (*11*), 1943	do	Shipping		18.2	
	Unpared dorsal side	do		15.5	
Washington, (*168*), 1944	Pared cheeks, suture, and back.	Canning [3]		5.5 to 10.0	
Washington, (*218*), 1944	Pared cheeks	Shipping			12.5 and 21.0
		Canning			6.0 to 7.0
Illinois, (*60*), 1944	Unpared cheeks	Immature	10.0 to 12.0		
		Firm ripe	7.0 to 8.0		
		Tree ripe	3.0 to 5.0		
Illinois, (*123*), 1944	do	Least	10.5 and 11.5		
		Intermediate	9.1 and 10.1		
		Most	7.0 and 8.6		
Colorado, (*80*), 1946	Pared cheeks	Shipping		10.0 to 13.0	
Ontario, Canada, (*212*), 1947	do	Optimum		11.1	
Ontario, Canada, (*213*), 1947	do	Shipping		4.0 to 12.0	
Colorado, (*121*), 1947	Unpared cheeks	Hard		17.1	
		Firm		14.2	
		Tree ripe		5.5	
Illinois, (*170*), 1947	Pared cheeks	Early			28.0

[1] For other varieties, see table 3.
[2] Italic numbers in parentheses refer to Literature Cited, p. 92.
[3] Recommended pressure test for picking. Others, pressure test on specific lots of fruit.
[4] Fruit from moderately vigorous trees.
[5] Shaded fruit from highly vigorous trees.
[6] Fruit from weakly vigorous trees.
[7] See footnote 8, p. 15.

TABLE 3.—*Firmness (indicated by pressure test) of several peach varieties*[1] *at different stages of maturity and from different sources*

Variety, source, authority,[2] and date of report	Tests made on—	Stage of maturity	Pressure test with plunger diameter of— 5/16 inch	7/16 inch
			Pounds	*Pounds*
Belle				
Virginia, (*82*), 1939	Pared cheeks	Shipping	12.5 to 14.0	
Maryland, (*78*), 1939	do	do	13.0 to 17.5	
Georgia, (*143*), 1939	do	Hard	19.8	
		Firm	16.5	
Carman				
Virginia, (*82*), 1939	do	Shipping	9.0 to 12.0	
Cumberland				
Illinois, (*170*), 1947	do	Early		25.0
Early Crawford				
California, (*140*), 1926	do	Shipping	14.0 to 20.0	
Early Elberta				
Utah, (*45*), 1933	Unpared cheeks	do	14.0 to 18.0	
Golden Jubliee				
British Columbia, Canada, (*67*), 1943	do	do	14.3	23.3
Ontario, Canada, (*212*), 1947	Pared cheeks	Optimum	9.3	
Illinois, (*170*), 1947	do	Early		16.5
Halehaven				
Illinois, (*170*), 1947	do	do		24.0

Hiley				
Georgia, (*145*), 1937	do	Hard	10.0 to 17.0	
Georgia, (*143*), 1939	do	do	16.2 to 18.2	
		Firm	13.8 to 14.4	
J. H. Hale				
Utah, (*45*), 1933	Unpared cheeks	Shipping	12.0 to 17.0	
Virginia, (*82*), 1939	Pared cheeks	do	11.0 to 16.0	
Maryland, (*78*), 1939	do	do	17.1	
Washington, (*72*), 1941	do	do	12.2 and 13.9	
Washington, (*11*), 1943	Unpared (?) cheeks	do	17.9	
	Unpared (?) dorsal side	do	16.4	
British Columbia, Canada, (*67*), 1943	Unpared cheeks	Early	15.8 and 16.3	25.1
Rochester				
Ontario, Canada, (*228*), 1941	do	do	19.0 to 20.0	
British Columbia, Canada, (*67*), 1943	do	do	14.9 and 15.7	22.6
Triumph				
California, (*140*), 1926	Pared cheeks	Shipping	11.0 to 14.0	
Tuscan				
California, (*140*), 1926	do	do	8.0 to 14.0	
Valiant				
British Columbia, Canada, (*67*), 1943	Unpared cheeks	Early	14.7	25.3
Vedette				
British Columbia, Canada, (*67*), 1943	do	do	15.7 and 16.2	21.8
Veteran				
British Columbia, Canada, (*67*), 1943	do	do	15.8	19.8
Ontario, Canada, (*212*), 1947	Pared cheeks	Optimum	9.4	

[1] For Elberta, see table 2.
[2] Italic numbers in parentheses refer to Literature Cited, p. 92.

In general, those who have investigated indexes of peach maturity have recommended the pressure test as one of the better indexes (Magness and Allen (*140*), Morris (*162*), Blake and others (*21*), Coe (*45*), Willison (*228*), and Upshall and Van Haarlem (*212*)). However, its use has definite limitations because of the inconsistencies that Coe (*45*), Britton (*29*), Mallison, Bratley, and Wiant (*143*), Fisher, Britton, and O'Reilly (*67*), and Haller [13] have pointed out and, therefore, discretion is needed in the application of the pressure-test data. It would appear valuable for establishing minimum maturity standards for specific purposes, as an objective measurement to avoid fruit so immature that it will not ripen with satisfactory quality. The ranges in firmness of Elberta peaches at different stages of maturity, as reported by various investigators, are presented in table 2. In some cases the ranges are determinations made from specific lots of fruits, while in others they are recommended ranges for picking. Similar data for other varieties are presented in table 3.

In addition to changes in firmness of the flesh, as shown by the pressure test, the flesh texture changes from a tough, woody condition in which the flesh crackles when cut or broken and is granular in appearance, to a firm condition in which the flesh cuts smoothly and lacks a granular appearance. There seems to be no experimental study reported on the relation of these texture changes to maturity, although they are sometimes used by the Inspection Service of the United States Department of Agriculture in conjunction with other tests to establish the maturity of questionable lots.

COMPOSITION

Changes in composition, such as the ratio of soluble solids to acids, are used as an index of maturity in some fruits.

Tindale, Huelin, and Trout (*207*) determined soluble solids, total acids, ascorbic acid, and catalase of peaches from different pickings. They concluded that the relation of these constituents to maturity was hardly close enough to warrant their use as maturity indexes. Soluble solids were determined during maturation of two varieties of peaches, by Willison (*228*). Although there was a tendency for the solids to increase with advance in maturity, the trend was neither definite nor consistent enough to serve as an index of maturity. Reyneke (*183*) observed a marked increase in ratio of solids to acids with advancing maturity—the ratio being 15 to 16.3 in the hard-green stage, 17 to 20 in the firm-turning stage, and 20 to 30 in the soft-yellow (nearly tree-ripe) stage. Fisher, Britton, and O'Reilly (*67*) considered the difference in percentage of solids between mature and immature peaches too small to use as an index of maturity. Neubert and others (*165*) also found that the percentages of soluble solids and sugars did not vary appreciably during maturation or ripening. The change in ratio of soluble solids to acids is due largely to a

[13] Unpublished data.

decrease in acidity, since total soluble solids generally remain fairly constant. Results reported by the various investigators do not indicate any definite relationship between percentages of soluble solids and acidity that could be used as an index of maturity.

Reyneke (*183*) observed a change in the amount of juice that could be expressed from peaches at different stages of maturity. He does not suggest this as an index of maturity, but he implies that the method of handling the fruit for storage (delayed ripening) would differ, depending on their juiciness when picked. This relationship has not been checked by other investigators, but work along this line seems desirable.

TASTE

Although not an objective test, taste may give an indication of maturity. Much of the bitter and astringent taste of immature fruit may be lost as it becomes mature. There seems to be no recent published evidence relative to the value of this character as an index of maturity.

SUMMARY AND DISCUSSION OF MATURITY INDEXES

One of the big problems of the peach industry is that immature peaches of relatively poor dessert quality are sometimes marketed. This tends to decrease the price and demand for subsequent offerings. In order to control this situation it is necessary that inspectors have some reasonably definite and objective means of distinguishing mature from immature fruit in early pickings of a variety as it comes into the packing house. Such an index has not yet been established, although firmness as determined by pressure test seems to be the nearest approach. With a plunger 5/16 inch in diameter, the maximum pressure in tests on cheeks of Elberta peaches at shipping stages of maturity was usually 18 to 20 pounds through the skin or 14 to 16 pounds on the pared flesh, as shown in table 2. If the higher figures of 20 pounds unpared or 16 pounds pared were used as a standard, it seems likely that under some conditions the fruit would be of rather poor quality and verging on the immature. The lower figures of 18 pounds unpared or 14 pounds pared probably could be used as the maximum pressure for fruit of good shipping quality, and would be preferable for use in establishing maturity.

PICKING AND HAULING

Detailed instructions for picking peaches are given by Morrison (*164*). Picking is an important operation, since the pickers are largely responsible for selection of the fruit of proper maturity. If picking is not carefully done, the operation may be the source of much bruising and injury. Despite the importance of the operation, relatively few experimental studies have been made of it. Overholser and others (*172*) observed that when the pickers were careful to pick only fully mature fruit, they were slowed to

40 to 75 percent of their normal rate under commercial conditions in Washington. Hitz, Simons, and Schell (*108*) have shown that in commercial picking 36 to 46 percent of the fruits were ruptured at the stem. After the peaches had gone through the packing operation, 73 to 80 percent of the stem ruptures became infected with brown rot. When stem ruptures were reduced to zero by careful picking, decay was greatly reduced. A reduction in weight loss after harvest has been reported in Georgia (*69*) for peaches that were picked with a short section of stem attached, as compared with no stem.

Lloyd and Newell (*132*) and Matsumoto (*149*) have noted the great difference in the temperature of fruit in the early morning and in late afternoon. They suggest the desirability of picking the fruit early in the morning to take advantage of the lower temperatures. As this would be of benefit only if the fruit were packed and placed under refrigeration promptly, it would seldom be practical in commercial practice, as packing operations frequently extend through the day and sometimes into the night during the main harvest period. It would be of greater practical importance to have the harvesting and packing operations planned so that there is little delay between the time peaches are picked and the time they are placed under refrigeration.

Bruising and mechanical injury to the fruit during picking and hauling will be considered later along with that occurring in the packing house and during shipment.

GRADING AND PACKING

Grading and packing operations vary greatly, from those practiced in small-grower sheds, in which relatively simple machinery is used, to large community sheds where fruit from many growers is packed. With careful supervision a good job can be done under either circumstance. There appear to be only a few recent reports of investigations on the physical effects of the various packing-house operations.

BRUSHING

Brushing peaches to remove the fuzz is an almost universal practice. Dorsey and Potter (*61*) made microscopic examinations of peach hairs before and after brushing. They found that peach fuzz consists of long and short hairs. The long hairs were broken off near the base by brushing and other handling, but the short hairs were not. Dorsey and Potter thought that the greater susceptibility of brushed fruit to decay was probably due to the closer contact of spores to the surface of the fruit rather than to the broken hairs providing points of entry. This conclusion was substantiated by Smith (*199*), who inoculated brushed and nonbrushed peaches with brown rot spores. Histological examination showed that the germ tubes from the spores grew down the sides of the hairs of nonbrushed fruit, and infection occurred

primarily at the hair sockets of unbroken hairs. On brushed peaches, infection also occurred primarily at the hair sockets, and infection occurred sooner because of closer proximity of the spores to the point of infection. Hitz, Simons, and Schell (*108*) found that brushing increased brown rot in stem-ruptured peaches, from 59 percent in a sample taken before brushing to 72 percent in a sample taken after brushing. Brushing apparently inoculated wounds that had not previously been inoculated with decay-producing organisms.

BRUISING

Bruising of apples has been found to vary greatly among different orchards and among individual pickers in the same orchard. This would probably be equally applicable to peaches, but no investigations along this line have been reported. Kelley and others (*124*) reported that 8 percent of the peaches were bruised when picked into picking bags and then placed in field crates. Bruising showed an increase to 9.6 percent after the fruit was hauled and unloaded at the packing shed (an increase of only 1.6 percent). Although many of the fruits bruised during picking and hauling were sorted out during grading, the grading and packing caused enough additional bruising to maintain 7 to 9 percent of bruised peaches in the packed fruit.

Jorgensen and Ornelas (*121*) determined the average amount of damage to peaches for five growers who packed in bushel baskets and for five other growers who packed in lug boxes. Damage (bruised or stem-punctured) from picking and handling in field crates averaged 9 and 12.3 percent for the baskets and boxes, respectively. Shed operations resulted in additional damage of 20.6 percent for fruit packed in baskets, but only 4.8 percent for fruit packed in boxes. In boxes there was an additional 5 percent damage during hauling from the packing shed to the loading platform. Also there was 23.2 percent (for baskets) and 21.3 percent (for boxes) of the peaches with growth blemishes. This gave a total of more than 50 percent of blemished or damaged fruit in baskets, and of 43.4 percent in boxes, before they were loaded into the cars.

Alderman (*4*) determined the source and amount of bruising of nearly tree-ripe Golden Jubilee and Elberta peaches during two seasons. He found that bruising while the fruit was still on the trees averaged 14 and 9 percent, respectively, for the two seasons. Bruising increased to 39 and 36.5 percent during picking and hauling. The amount of bruised fruit was reduced about 20 percent as a result of culling, but transit bruising brought the percentage up to about 42 and 35 percent, respectively, for the two seasons. Transit bruising varied considerably, depending on the type of shipping container used.

Cravens and Mauch (*47*) compared bruising of tree-ripe peaches with those picked at the usual shipping stage of maturity. Noticeable bruising from picking and hauling was 33 percent in

the tree-ripe fruit and 7 percent in fruit of shipping maturity. Grading and packing operations caused bruising to an additional 25 percent of the tree-ripe fruit, but very little bruising to the shipping-mature fruit.

Much bruising takes place in transit and during handling in the terminal markets and retail stores. Studies of bruising in transit have been largely concerned with the effect of different types of packages, and will therefore be discussed in connection with packaging.

In some sections, as in southern Georgia, large hand-carried buckets are used as picking receptacles. In many sections regular drop-bottom picking bags or picking buckets with shoulder harness are used. If the more mature fruits are to be harvested, it becomes increasingly important that methods of picking be used that will give the greatest possible protection from bruising. Further investigations along these lines seem desirable. Studies on the sources and extent of bruising during the grading and packing operations are also needed.

PACKAGING

Studies of different types of packages for peaches have been concerned primarily with ventilation and rate of cooling and with protection of the fruit from bruising. The cost of the container, acceptance in the trade, and convenience and cost of packing are also of vital importance but are more in the field of economics.

In the Eastern and Central States, peaches for commercial shipments are packed almost entirely in bushel baskets which are faced and jumble-packed (*40*). In the Western States, flat boxes (inside dimensions of 11½ by 16⅛ by 4½ to 5½ inches) and Los Angeles (L. A.) lug boxes (13½ by 16⅛ by 5¾ inches), in which the peaches are sized, wrapped, and place-packed in two layers, are used extensively. Bushel baskets are of two general types: The continuous-stave round-bottom baskets and the export tub-type with a flat, sawed-wood bottom. The continuous-stave basket is less rigid than the export tub-type basket, and for this reason gives less protection from bruising. Overlapping of the staves in the bottom results in sharp ridges that tend to bruise and cut fruit in the bottom layer. Consequently, continuous-stave baskets have been replaced almost entirely by the export tub-type baskets as containers for peaches. A few continuous-stave half-bushel baskets are still used in some places.

The export tub-type baskets are made with tight sides or with spaces of ⅜ to ⅝ inches between the staves for ventilation. The sides of the baskets are usually lined with heavy paper that is made with or without round or slotted holes for ventilation. Cooling of the fruit has been found to be appreciably faster in vented baskets with vented liners than in baskets with solid sides and solid liners (Hienton and Fawcett (*105*), Lloyd (*131*), Fawcett and Burkholder (*65*), and Jorgensen and Ornelas (*121*)). Consequently, liners with round or slotted holes, and baskets that

permit ventilation through the sides, have become fairly standard for peach shipments. Ventilated and nonventilated baskets of similar construction should be equally effective in protecting the fruit from bruising, although Alderman (*4*) presented data that indicated more bruising in vented baskets than in nonvented baskets. On the basis of these data he rated the nonvented baskets as superior to the vented type, although the vented type is generally considered more desirable because it facilitates cooling. Since venting should not affect protection from bruising, the greater amount of bruising reported for the vented baskets may have been because of experimental error.

Pads or cushions are used under the lids to prevent bruising of fruit in the top of the baskets. Pads of corrugated cardboard are sometimes used, but cushions made of paper outside layers and filled with shredded paper or excelsior are more commonly used. These pads and cushions have insulating properties and prevent the circulation of air through the lid. Mallison (*141*), Mallison, Bratley, and Wiant (*143*), and Mallison and Wiant (*145*) investigated the desirability of increasing the ventilation through the basket by using a pad made with a round hole in the center. In a number of test shipments of peaches with such pads, it was found that cooling was slightly faster with the vented pads. They stated (*143*) that the use of vented pads added about 1 day to the time required for the fruit to ripen to the best condition for the retailer. The data do not entirely support this conclusion, however, as in many of the shipments there was very little or no difference in the time required to ripen.

In these test shipments there were only a few baskets with the vented pads in carloads of baskets with regular pads. Mallison, Bratley, and Wiant (*143*) stated that differences between vented and nonvented pads would probably be greater with solid carloads of each type pad. This seems questionable because the air would be warmed less in passing around nonvented baskets of peaches, and being cooler would remove more heat from a few vented packages present, than if the entire load were vented. Hienton and Fawcett (*105*) determined the effect of four holes 1 by 4 inches cut in the pad and alined with similar holes in the lid on the rate of precooling peaches. The rate of cooling with such ventilation as compared with cooling in baskets with nonvented pads was faster by 0.4° to 0.7° F. per hour in the top of the load, but was 0.3° slower in the bottom. Here again the comparison was with only a few baskets with added ventilation in a carload, without the extra ventilation that might tend to accentuate the difference. Fawcett and Burkholder (*65*) showed a 5° difference with similar vented pads at the end of a short precooling period, but showed only 1° after 43 hours in transit.

Haller and others (*83*) also compared vented and nonvented pads in nonfan and fan cars, but used entire carloads with each type of pad. They used perforated pads (48 holes of ½-inch diameter) and slotted pads (6 slots about ¾ by 4 inches to coincide with openings in lids). Although the increased ventilation

was of some benefit in the nonfan cars, there was no appreciable benefit in the fan cars. Even in the nonfan cars, the temperature difference was not enough to make an apparent change in the condition of the fruit.

The need for additional ventilation through the bottoms of baskets has also been studied. Tub baskets are usually made with a small (about 5/8-inch) hole in the center of the bottom. Fawcett and Burkholder (*65*) found that four 1¼-inch holes in the bottoms of ventilated baskets greatly increased the rate of cooling. At the end of 5 hours of precooling in a fan car, commodity temperatures averaged 14° F. lower in baskets with the added ventilation through the bottoms than in baskets with no ventilation. Only a few baskets with the added ventilation were loaded into a car with baskets without the extra ventilation. When entire carloads of each type of basket were compared, no significant difference was found by Redit, Haller, and Kaufman (*182*) in the temperatures en route or in the condition of the fruit on arrival. The extra ventilation for full-carload tests consisted of two slots approximately 5/8 by 6 inches in the bottom.

It has been pointed out by Haller and others (*83*, *86*) that the total area of opening for ventilation in baskets with slotted liners is small (about 3.4 square inches). Furthermore, openings in the side permit only horizontal air movement through the baskets. whereas the air movement in cars is largely vertical. Additional openings through the top or bottom should be desirable. Tests with only a few such baskets in carloads of standard baskets show a benefit. However, such tests probably accentuate the differences. In a limited number of tests where full carloads of each type of basket were compared, no difference of practical significance was obtained. Additional tests of carload lots of baskets with added ventilation through the tops or bottoms would be desirable, as well as tests in which openings for ventilation are added to both the top and the bottom of the baskets so that vertical air movement through the baskets would be possible.

Half-bushel baskets are sometimes used for shipping peaches, particularly for small fruit of early varieties. Theoretically, this might be expected to permit more rapid cooling of the fruit—because of the greater surface exposed in proportion to the weight, as compared with a bushel basket. Less bruising might also be expected—because of less weight on fruit in the bottom of the basket. However, Haller and others (*83*) found no difference in rate of cooling in transit of peaches in half-bushel baskets, as compared with those in bushel baskets. There was also no significant difference in the amount of bruising. It was suggested that the pressure of the lid of overfilled half-bushel baskets may be as damaging as the weight of the fruit in larger containers. Alderman (*4*) also showed no consistent difference in the amount of bruising of peaches in half-bushel and bushel baskets. However, with careful attention to racking during filling and by not overfilling, it should be possible to ship peaches in half-bushel baskets with less bruising than in bushel baskets. Despite this possi-

bility, the experimental tests indicate that the additional cost of packing half-bushel baskets can hardly be justified on the basis of additional protection for the fruit.

Bushel boxes, both wire-bound veneer and nailed, sawed-wood, have been tried as possible substitutes for bushel baskets. Boxes have an advantage in that they stack more compactly than baskets; consequently, with the same height of loading, more fruit can be loaded into the cars. A carload of bushel baskets stacked three high is usually 396 baskets. If also stacked three high, 464 Spartan boxes (wire-bound) and 534 sawed-wood boxes can be loaded in a car.

The bushel Spartan box has inside dimensions of 11 by 11 by 19 inches. There are spaces about ½-inch wide between the veneer slats on the sides and ends for ventilation. Solid pads are used in the top and bottom, and ventilated liners around the sides and ends. The boxes are loaded on their sides, which permits vertical air movement through them. Results of comparisons between bushel Spartan boxes and bushel baskets have not been consistent. Hauck (*93*) and Alderman (*4*) found much less bruising of peaches when shipped in Spartan boxes than when shipped in bushel baskets. Redit, Haller, and Kaufman (*182*) and Breakiron and Hoecker (*27*) found no appreciable difference; and Kelley and others (*124*) found less bruising in baskets than in boxes.

The Spartan boxes are usually filled with little or no bulge, and bushel baskets usually have considerable bulge. Differences in peach bruising between baskets and boxes may be due to the degree of fill in the containers. Kelley and others (*124*) reported net weight of 49.5 pounds in the bushel basket, and 51.2 pounds in the Spartan box. Corresponding net weights reported by Breakiron and Hoecker (*27*) were 52.3 pounds and 52.8 pounds, respectively, for baskets and boxes. A fill of 49.5 pounds in the bushel basket was probably a slack pack. In this connection, Haller and others (*86*) shipped peaches in bushel baskets with different degrees of fill ranging from 49.4 pounds (slack pack) to 52.8 pounds (full pack). Differences in bruising in transit were small, but even the baskets with the heaviest fill were not as heavy as some commercial packs. However, degree of fill and care in packing may be more important in preventing bruising than the type of container. Additional studies along this line would be desirable.

There is also disagreement on the rate of cooling of peaches in bushel baskets and Spartan boxes. With individual containers in a cold-storage room, Alderman (*4*) reported that the rate of cooling in the Spartan box was 7.0° F. per hour and was appreciably faster than in the bushel basket, where the rate was 5.1° per hour. Redit, Haller, and Kaufman (*182*), in a test shipment with full carloads of peaches in each type of container, found no appreciable difference either during precooling or in transit in either fan or nonfan cars. However, because of the heavier load with boxes, more heat was removed from that load. Breakiron and Hoecker (*27*) indicated much heavier breakage in carloads of baskets than in carloads of Spartan boxes. They found that al-

most 10 times as great a percentage of baskets as of boxes arrived in bad order (too badly damaged for repair).

Spartan boxes of half-bushel capacity are also available. However, Alderman (*4*) found no difference between the half-bushel and bushel Spartan box in amount of bruising or rate of cooling of peaches.

Sawed-wood apple boxes have also been tried for peaches. Merrill (*152*) found that peaches were bruised slightly less when shipped in Northwest apple boxes than in bushel baskets; but baskets were more acceptable to the consumers. Cravens and Mauch (*47*) shipped Halehaven and Elberta peaches in bushel boxes and baskets. There was relatively little bruising, but in both varieties there was more with the boxes than with the baskets. However, there was less decay in the boxes than in the baskets, and because of this the percentage of defective peaches was less in the boxes. Hitz, Simons, and Schell (*108*) also reported less decay in peaches shipped in boxes than in baskets, presumably due to more rapid cooling of the fruit in the boxes.

Greve (*74*) found fruit temperatures were 2° to 7° F. lower in ventilated boxes than in nonventilated baskets after 18 hours in a draft of night air to simulate truck shipments. However, in one test when ventilated instead of nonventilated baskets were used there was no difference. Haller and others (*86*) found that cooling in carlot shipments was somewhat faster in boxes than in ventilated baskets in either fan or nonfan cars. The boxes were made with solid sides and had pads top and bottom. Ventilation was through openings (about ½ by 16 inches) between the sides and the top and bottom of the boxes. This gave a total opening of about 32 square inches for ventilation in boxes, as compared with about 3.4 square inches in the lined baskets. Another factor in the more rapid cooling in the box load was that with a solid load of boxes there is very little space for air circulation between the containers. Therefore, there was a greater tendency for the air to circulate through the containers and around the fruit. The reduced temperatures in boxes during transit did not significantly affect brown rot, but they apparently reduced rhizopus rot in one shipment. Bruising was not serious in either container, but it was slightly less in the boxes.

Flat lug boxes containing about 16 pounds of sized, wrapped peaches packed two layers deep are extensively used in the Western States. The lugs have cleats on the lids so that when the lugs are stacked there is space of about ½ inch between the layers of boxes. The boxes are usually loaded with a space of 1 to 2 inches between the rows. Haller (*80*) found no appreciable difference in rate of cooling of peaches in boxes (1,400 per car, loaded 10 high and 7 wide) and in nonventilated bushel baskets (528 per car, loaded 4 high). Using individual packages in a cold room (44° F.), Jorgensen and Ornelas (*121*) found that peaches cooled appreciably faster in either ventilated or nonventilated baskets than in lug boxes. Haller (*80*) shipped tree-ripe peaches (average pressure test of 4.4 pounds with 5/16-inch plunger on pared

cheeks) in lug boxes. Although there were three times as many bruised peaches in the tree-ripe peaches as in peaches of standard maturity (average pressure test of 9.5 pounds when packed), the tree-ripe peaches arrived in good marketable condition after 7 days in transit, when shipped in fan cars or in the bottom layers of nonfan cars. The results indicated the suitability of the lug box for handling peaches of very advanced maturity, provided they can be cooled promptly and are less than a week in transit.

Tests also have been made with containers in which the peaches are separated from each other. This may be done with cell-type cartons in which the fruit is separated by corrugated-cardboard partitions, as in egg crates, or by pressed forms with rounded depressions into which the fruit fits (Friday pack or Kyspak). Use of these types of containers makes it necessary to separate the fruit into different sizes and to stock different-size cells or forms. Merrill (*154*) stated that the cost of the cell-type containers and the cost of packing them are about equal to the cost and packing in bushel baskets.

According to Alderman (*4*), the rate of cooling of the fruit was 4.6° F. per hour in cell-type cartons and 5.1° for pressed forms in cartons, as compared with 6.2° and 5.1° in bushel baskets. These rates of cooling were of individual containers in a cold room, which probably were more than differences that might be expected in actual shipments.

In nearly all reports, bruising has been found to be appreciably less in cell-type cartons than in bulk containers such as bushel baskets. Merrill (*155*) reported only 4.0 percent bruising in 96-cell cartons, and 31 percent in bushel baskets. Hauck (*93*) found 14 and 11 percent bruising, respectively, in 96- and 48-cell cartons, and 60 percent in bushel baskets. Kelley and others (*124*) reported 11.8 percent average bruising in 80-, 96-, and 120-cell cartons, and 28.1 percent in baskets. Cravens and Mauch (*47*) observed a total of 0.1 percent defective peaches due to bruising in cell cartons, and 1.0 percent in baskets. Alderman (*4*) reported 16.7 percent bruising in 96-cell cartons, 31.2 and 11.5 percent, respectively, in vented and nonvented baskets, only 1.5 percent in tomato lugs, and 3.0 and 2.8 percent, respectively, in bushel and half-bushel Spartan boxes.

Decay also has been less in cell cartons than in bulk containers, apparently due to separation of the fruit, which prevents or retards spread of decay from one fruit to another. In this connection Merrill (*155*) found decay to be 4.5 percent in 96-cell cartons, and 16.2 percent in baskets; and Cravens and Mauch (*47*) found the percentage of defective peaches because of decay to be 12.2 percent in cell cartons, and 24.5 percent in baskets.

Merrill (*155*) observed that peaches shipped in cell-type cartons sold 50 percent faster and at an 11-percent-higher price than those shipped in bushel baskets.

The experimental evidence presented indicates that cell-type cartons would be desirable shipping containers for peaches because of the protection from bruising and spread of decay that

they afford. Although it has been reported that the cost for these containers and for packing them is no more than for bushel baskets and packing, the evidence for this is not conclusive. The protection from bruising and spread of decay should outweigh the disadvantages of requiring sizing of the fruit and the stocking of partitions of different sizes. However, the manager of one large shipping organization has been quoted (*3*) as saying that cell-type cartons are unsuitable for large-scale commercial operations because of the extra cost and large number of different-size cells required.

Cardboard cartons of different types also have been tried. McMunn and others (*138*) observed that bruising was less in a carton of 6/7 of a bushel capacity than in a basket of half-bushel capacity. Later McMunn and others (*137*) made two shipments of peaches of advanced maturity in three different types of cartons and in bushel baskets. Bruising in the cartons ranged from 17.2 to 19.8 percent, as compared with 28.1 percent in the bushel baskets. The net weight of fruit in the cartons ranged from 45.5 to 51.1 pounds, and averaged 50.1 pounds in the baskets. Kelley and others (*124*) reported a similar reduction in bruising, from 28.1 percent in baskets to 16.3 percent in hinge-top cartons. Hauck (*94*) indicated that a flat half-bushel carton was not satisfactory, as it did not adequately protect the fruit from bruising at the top and bottom, and it lacked ventilation for cooling. Jorgensen and Ornelas (*121*) found the rate of cooling of peaches in a vented bushel carton to be intermediate to the rate in vented and nonvented baskets when individual packages were held in a cold room. Peaches in consumer packages in vented cartons were much the slowest to cool.

In general, the results indicate a slight reduction in bruising with bushel cartons as compared with bushel baskets, but they do not indicate sufficient benefit to warrant adoption of the cartons.

Hauck (*93*) and Kelley and others (*124*) found that fiberboard drums materially reduced bruising, but disadvantages in such factors as size, shape, and convenience were considered to outweigh the advantages.

Alderman (*4*) found that bruising of peaches in tomato lugs (dimensions not given but presumed to be 6 by 13½ by 16 inches) was much less (1.5 percent) than in bushel baskets (31.2 and 11.5 percent), and even less than in cell-type cartons (16.7 percent). In a general rating of performance, the tomato lug was given the highest score, but it was unacceptable to the trade.

Upshall and Wilson (*213*), in Canada, shipped peaches in various small containers. Less bruising was found in a single-layer cell-type carton than in 6-quart heaped baskets and nailed or wirebound boxes of 16- to 17-pound capacity (similar in size and shape to the 16-pound western peach lug). Upshall and Wilson indicated that if the peaches were wrapped they carried well in the 16- to 17-pound boxes.

Hauck (*93*) reported negligible bruising in 4-quart baskets (shipped six to a master carton) as compared with 60-percent

bruising in bushel baskets. On the other hand, Cravens and Mauch (*47*) found 1.7-percent bruising of Halehaven peaches shipped in 4-quart baskets, as compared with 1.0 percent in bushel tub baskets.

Hauck and Luke (*95, 96*) shipped peaches in cell-type consumer cartons containing 12 peaches (2½ inches) per carton, and packed 12 consumer cartons per master carton. Data on bruising are not presented, but the investigators state that the prepackaged peaches sold at a premium of $1.00 to $2.00 per bushel. The cost of the cartons was $0.85 per bushel.

As an example of the extreme care that may be practiced under some circumstances, Micklem, Du Preez, and Black (*157*) and Micklem and Du Preez (*156*) described shipping tests from South Africa in which peaches were packed in single-layer trays (boxes), with excelsior or other packing material completely surrounding each fruit in some instances. They recommended as most practical a solid pack of wrapped peaches without padding between the fruit but with excelsior padding at the sides and ends of the trays.

For shipping hard peaches of the usual shipping maturity, the ventilated bushel tub basket is economical, has given satisfactory service, and has been generally acceptable to the trade. When soft ripe peaches are packed in bulk containers of a bushel capacity, the weight of the fruit tends to bruise and crush those in the bottom. Therefore, if the fruit is picked in an advanced stage of maturity or is likely to become ripe and soft in the shipping container, a smaller container or a cell-type container is necessary if excessive bruising is to be avoided. Experimental results have shown that certain containers give greater protection from bruising than the bushel basket; but they have not been adopted generally, except in the West, because of greater cost of container, increased cost or inconvenience of packing, or for other reasons, the most important of which may be lack of acceptability by the trade.

WAXING

Although wax coatings have been used on a number of fruit products to retard moisture loss, there have been relatively few attempts to wax peaches. Allen (*7*) reported on experiments in California on the waxing of nectarines and of peaches that had been defuzzed. He stated that wax emulsions were more effective in reducing moisture loss from peaches than from many other fruits, but he also stated that with use of the emulsions decay tended to increase when spores were present on the fruit.

WRAPPING AND PREPACKAGING

Peaches grown in the West are usually wrapped in plain tissue wraps when shipped in lug boxes. The wraps have some cushioning effect and may retard somewhat the spread of decay. Judkins (*122*) reported that decay was halved by use of tissue wraps.

They also retard somewhat the cooling of the fruit. Jorgensen and Ornelas (*121*) questioned the desirability of wrapping peaches because of the possible effect on cooling in transit.

Recent investigations on wrapping have been concerned primarily with plastic materials, including sealing the fruit in plastic bags. Stahl and Cain (*204*) and Stahl and Vaughan (*205*) reported favorable results with a rubber film (Pliofilm). They stated that wraps of this material greatly reduced weight loss, shriveling, and decay and extended the storage life of, and time required to ripen, four varieties picked at two stages of maturity and stored at four different temperatures. No effect of the treatments on the flavor of the fruit was indicated. Judkins (*122*) also used Pliofilm with five varieties of peaches held at 70° and 40° F. When sealed in Pliofilm bags or stretch-wrapped with Pliofilm, the fruit developed off-flavors. Decay was nearly doubled when the peaches were wrapped in sheets of Pliofilm without sealing.

Jorgensen and Ornelas (*121*) prepackaged tree-ripe peaches and over-wrapped the packages with MSAT, LSAT, and LST Cellophane, cellulose acetate, and Pliofilm. Deterioration of the fruit was most rapid in the films (such as Pliofilm and MSAT Cellophane) with greatest resistance to the passage of moisture. The investigators concluded that of the films tested, LSAT Cellophane was the most desirable for the commercial prepackaging of peaches. It was rated superior to cellulose acetate primarily because of its greater strength and heat-sealing characteristic.

Hruschka and Kaufman (*112, 113*) found that tightly sealed MSAT and LSAT Cellophane both were unsuitable for peaches, because of off-flavors that developed even at temperatures as low as 45° F., maintained for 1 to 3 days. They observed that even cellulose acetate caused off-flavors under some conditions. Perforated (two 3/16-inch holes per package) Cellophane protected the fruit from moisture loss, and no off-flavors developed. In a later test, Hruschka (*111*) reported on the use of "electro-perforated" DSB–1 Cellophane. Two degrees of perforation of this Cellophane were used, one of which permitted 50 cubic centimeters (cc.) of air, under a pressure of 20 ounces per square inch, to pass through 1 square inch of surface (DSB–1–88) in 88 seconds, and through the other surface (DSB–1–188) in 188 seconds. At room temperatures there was very little accumulation of CO_2—less than 2.5 percent—and no off-flavors with DSB–1–88. With the film of 188 porosity, the concentration of CO_2 became very high. Off-flavors developed within a day and then became progressively worse.

From the above results it is apparent that peaches cannot be tightly sealed in films that inhibit gaseous exchange or moisture transmission. Peaches develop off-flavors under anaerobic conditions, and decay is likely to be increased with high humidity. Additional evidence on the effect of CO_2 on peaches is presented in the section on controlled-atmosphere storage (p. 50).

RIPENING

TERMINOLOGY

The ripening process in peaches, or changes that make the fruit suitable for use, may take place either on or off the tree. It consists primarily of softening, development of juiciness, and development of flavor. Blake and Davidson (*20*) designated three degrees of ripeness, and gave the pressure-test range of each. Peaches testing 12 to 14 pounds (5/16-inch plunger through skin of cheeks) were designated as "hard ripe," those testing 8 to 11 pounds as "firm ripe," and those testing 6 pounds or less as "ripe." Mallison and Haller (*144*) designated degrees of ripeness as "hard" with pressure-test readings for Elberta of 8.5 pounds or more (5/16-inch plunger on pared cheeks); "firm" and "firm ripe" with pressure-test readings of 3.5 to 8.5 pounds; and "ripe" and "soft ripe" with pressure-test readings of 3.5 pounds or less. Fisher and Britton (*66*) defined three degrees of ripeness as "unripe"—hard to firm fruit; "ripe"—ready to eat; and "overripe"—too soft for sale.

The Inspection and Standardization Service of the Production and Marketing Administration uses the following terms to describe ripeness at terminal markets: "Hard" means that the peach does not yield to moderate pressure. This is the stage at which peaches are usually picked when long keeping or carrying qualities are the prime considerations; "Firm" means that the peach yields very slightly to moderate pressure and is not yet edible; "Firm Ripe" means that the peach yields slightly to moderate pressure, is fairly palatable but not in prime eating condition; "Ripe" means that the peach yields readily to moderate pressure and has reached the best eating condition; "Soft" means that the peach has very little resistance to slight pressure. The term "overripe" is not used. Fisher and Britton (*66*) are technically correct in designating peaches as either ripe or unripe. However, it is frequently desirable to distinguish different degrees of unripeness. The terms "hard," "firm," and "firm ripe," as used by the Inspection Service, are well adapted to this purpose.

EFFECT OF TEMPERATURE

The influence of temperature on the rate of ripening and on the rate of development of decay and breakdown is of great importance from the standpoint of precooling, and refrigeration in transit and on the market. Only the effect of temperature on ripening will be considered here.

Harding and Haller (*82, 89, 90*) held a number of varieties of peaches at 32°, 36°, 40°, 50°, 60°, 70°, and 80° F. Ripening at 70° and 80° was quite rapid, with very little difference shown between the two temperatures. At 60° ripening was normal (no breakdown or off-flavors) but required about twice as much time as at 70°. At 50° ripening required about twice as much time as at 60° but was abnormal (off-flavors were developed). Fruit in

a hard condition held continuously at temperatures of 40°, 36°, and 32° failed to ripen, and they soon lost the ability to ripen normally even when transferred back to room temperatures. This ability was retained longer, however, when the fruit was held at 32° than when held at 36° or 40°.

Smith and Willison (*202*) held three pickings of Elberta peaches at 32°, 37°, 45°, and 60° F. There was little or no ripening at 32° and 37°, very gradual ripening at 45°, and fairly rapid ripening at 60°. Dorsey and McMunn (*60*) held three maturities of two varieties at 37°, 40°, 50°, 70°, 80°, and 90°. The fruit softened rapidly at 60° and above, with relatively little difference in the rate of softening between 70° and 90°. The rate of softening decreased rapidly as the temperature was lowered below 60°, particularly with the less mature fruit. Smith (*194*) observed that peaches ripened faster at 76° to 77° than at 65° or 90°. Neubert and Veldhuis (*167*) held peaches at 65° to 95°. They stated that the rate of ripening was accelerated by increased temperatures.

The results just mentioned show that temperature has profound effect on both the rate and type of ripening. At the outside temperatures that are likely to prevail during the peach-harvesting and marketing season, ripening is very rapid, with not much difference in rate between 70° and 90° F. The rate decreases rapidly at temperatures below 70°, and tends to become abnormal at temperatures of 50° or below; off-flavors develop when fruit is exposed 7 to 10 days at 50°, and breakdown develops after 10 to 14 days at 40° to 36°. Peaches can be ripened to good quality after about 10 to 20 days at 31° to 32°, depending on the variety and other factors. The question of the length of time peaches can be held at low temperatures will be discussed more fully under the section on storage (p. 44).

EFFECT OF ETHYLENE

Various fruits have been shown to give off ethylene and to be stimulated in ripening by exposure to low concentrations of this gas. Isaac (*117*) found that at room temperature peaches gave off a volatile material that inhibited the growth of certain seedlings. The volatile material was absorbed by bromine and was therefore presumed to be ethylene. Isaac showed later (*118*) that peaches were able to give off this volatile material also at the lower temperatures of 50° and 35° F. In most cases (*118*) ripening was not perceptibly accelerated by treating peaches with this material, although respiratory activity was stimulated somewhat at 90° (*119*). Later Isaac reported (*120*) that he obtained no stimulatory effect on peaches held at a low temperature (35°) for 3 weeks. According to Hansen (*88*), the pectic changes that are associated with softening were greatly accelerated in peaches treated with ethylene. In Georgia (*70*) it also was found that peaches gave off ethylene at 32° to 40°. Ethylene was found to hasten the ripening of peaches at room temperature, but to have no appreciable effect at 32° to 40°.

Acetylene has also been shown to influence the ripening of peaches. Partial ripening at room temperature before storage has been found to reduce woolliness, a low-temperature breakdown (see p. 48). Davies and Boyes (*49*) and Boyes and De Villiers (*23*) reported that ripening at room temperature could be hastened by treatment with acetylene. In this way a shorter period of delay was effective in reducing woolliness, and there was less loss of flavor.

EFFECT OF GROWTH REGULATORS

The effect of growth-regulating substances on the ripening of peaches has also been studied, with conflicting results. Southwick (*203*) treated Halehaven peaches, picked at a pressure-test reading of more than 30 pounds (5/16-inch plunger), with 2,4-dichlorophenoxyacetic acid in Carbowax, and also with the methyl ester and ethyl ester of alpha-naphthalene-acetic acid. After 3 days at room temperature, the pressure-test readings of the control lots (untreated and Carbowax only) were still 28.5 and 30+, respectively, whereas readings for the hormone-treated lots were only 3.8 to 6.0 pounds. The treatments also greatly increased the respiratory activity of the fruit. Softening and yellowing of the fruit was hastened by treatments made 1 to 3 weeks before harvest, but this treatment reduced the dessert quality of the fruit. The reduction was attributed to injury to the foliage. On the other hand, Gerhardt and Smith (*71*) obtained no response with Elberta and J. H. Hale peaches dipped in solutions of the sodium salt of alpha-naphthalene-acetic acid or 2,4-dichlorophenoxyacetic acid in Carbowax. These growth-regulating substances had no effect on the rate of ripening or pectic changes, although the respiratory activity was increased.

Marth, Harley, and Havis (*146*) and Marth, Havis, and Prince (*147*) made preharvest applications of a number of growth-regulating substances to peach fruit and leaves. Of the materials tried, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) was found to be the most active in hastening the maturity and ripening of the fruit. Some varieties were caused to ripen as much as a month in advance of normal by early application of 2,4,5-T at concentrations of 50 and 75 parts per million (p. p. m.). Treatments that advanced maturity this much caused the fruit to be misshapen and reduced in size and dessert quality. When treatments were applied closer to harvest, so that maturity was advanced only about 7 days, there was little or no effect on size or quality of the fruit. In fact, with such treatments fruit was observed to ripen more uniformly than usual. Treatment with 75 p. p. m. of 2,4,5-T caused moderate to severe damage to the foliage. A mild ripening response was obtained with concentrations as low as 5 p. p. m. Because of the danger of injury to the fruit and leaves, treatment with growth regulators is not recommended for commercial trial until further experimental tests have been made.

DESSERT QUALITY

The development of good dessert quality is of primary importance with peaches. The dessert quality of the fruit may be affected by a number of factors, such as variety, size of crop, soil fertility, soil moisture, weather conditions (particularly amount of sunshine), picking maturity, and temperature during storage and ripening. Blake and Davidson (*20*) associated good dessert quality in Elberta and J. H. Hale peaches with at least 7 percent of total sugars, 5 to 5.5 percent of sucrose, and less total acidity than the equivalent of 15 milliliters (ml.) N/10 NaOH in 10 ml. of juice.

EFFECT OF VARIETY

A number of studies have been made to determine the dessert quality and suitability of peach varieties for canning (*37, 214, 215*) and for freezing (*214, 215, 232*). The dessert and canning quality of most varieties of commercial importance are listed by Havis and others (*98*) and will not be discussed further here.

EFFECT OF THINNING

The primary purpose of thinning is to increase the size of the fruit. In addition, it has a decided influence on dessert quality. Moon and others (*160*) found that when peaches of 12 varieties were thinned to 6 inches apart, the fruit was superior in sweetness and flavor and in the balance of sugar to acid to astringency, as compared with unthinned peaches.

EFFECT OF WEATHER

Willison[14] observed that peaches had better quality when the weather before harvest was warm and bright and moderately dry than when it was wet, cloudy, and cool. With cool, cloudy weather there would probably be reduced photosynthesis with the result of less elaborated material for storage in the fruit. Under excessively wet conditions there would be a tendency for the water to enlarge the fruit and to dilute the soluble solids. Excessively dry weather might likewise result in fruit of poor quality by reducing photosynthetic activity.

EFFECT OF FERTILIZATION

The fertilizer element to which peach trees usually show the most marked response is nitrogen. Blake and others (*21*) obtained trees of different degrees of vigor largely by means of nitrogen fertilization. The growth status was also found to be influenced by soil moisture and severity of pruning. They found that

[14] See footnote 8, p. 15.

fruit from trees of high-nitrogen growth status was of lower edible quality than fruit from medium-high-carbohydrate growth status. Coe (*45*) observed a similar relationship in that fruit from highly vigorous trees was usually lower in sugars and poorer in dessert quality than that from moderately vigorous trees. On the other hand, Lott (*133*) found no apparent difference in quality as a result of nitrogen fertilization.

Williams and Veerhoff (*225*) obtained marked responses to borax applications to trees growing in a sandy soil. They observed that fruit from borax-treated trees was somewhat insipid compared with that from the control trees.

EFFECT OF SPRAYS

Since about 1940 many new materials have been introduced as insecticides and fungicides. One of these, benzene hexachloride (BHC), has been found to impart an off-flavor to the fruit. Davis (*53*) detected off-flavors in all samples of canned peaches sprayed with two applications of BHC. There seemed to be very little if any relation between the degree of off-flavor and the interval between the last spray application and harvest. Similar results were obtained by Bailey, Esselen, and Wheeler (*16*). They tasted 36 varieties that were picked 65 to 111 days after the last BHC application (three applications of BHC with 6 percent of the gamma isomer at the rate of 2 pounds per 100 gallons). In the fresh or frozen state no off-flavors were detected, although some peaches were lacking in flavor. However, when canned, all except four varieties showed slight to very strong off-flavor. These investigators, also, found no correlation between the length of time from the last application and harvest and the intensity of the off-flavor. Smith, Jones, and Calvin (*193*) sprayed Elberta peaches with combinations of parathion, chlordane, acid lead arsenate, sulfur, Phygon, and benzene hexachloride. The BHC was used in only two early (April) applications, but the quality of both the fresh and canned fruit was reduced. Reduction in the quality of the canned peaches was detected when parathion was included in the spray—but the difference, although statistically significant, was considered to be too small to be of any practical importance.

EFFECT OF MATURITY

The stage of maturity at which peaches are picked is of great importance in determining dessert quality. No entirely satisfactory objective index has been found with which to distinguish between mature peaches and those that cannot be ripened with satisfactory flavor. Consequently, peaches may sometimes be shipped that are immature. It has been well established that such peaches are of inferior quality (Fisher, Britton, and O'Reilly (*67*), Hall (*75*), and Cravens and Paul (*48*)) and should be kept off the market.

In recent years there has been considerable discussion and investigation of the possibility of marketing "tree ripe" peaches (Merrill (*150*), Cravens and Mauch (*47*), Hauck (*94*), and Kelley and others (*124*)), as it has generally been assumed that ripening on the tree is necessary to attain maximum dessert quality. This was indicated by Caldwell (*37*), who stated that peaches reach the highest quality and fullest flavor when allowed to become canning ripe on the tree. However, there is considerable evidence that peaches picked at the shipping stage of maturity can be ripened with good quality, and in some respects may be better than peaches ripened on the tree.

Mallison, Bratley, and Wiant (*143*) compared hard and firm peaches of commercial pickings. In most cases they were unable to distinguish any difference in dessert quality between peaches of the two maturities after they were ripe. Neubert, Veldhuis, and Clore (*168*) observed that peaches that required 6 days to ripen gave a better quality canned product than those picked at an earlier or later maturity. Later, Neubert and others (*166*) observed that the dessert quality of processed peaches was optimum when they were picked at an advanced shipping stage of maturity (requiring 3 to 6 days at room temperature to ripen). Such peaches were superior to those picked "tree ripe" (2 to 3 days to ripen). Van Blaricom and Musser (*215*) stated that peaches that were ripened off the tree were of better color and texture than tree-ripened fruit. Upshall and Van Haarlem (*212*), also, found that peaches picked at optimum shipping maturity ripened to good quality. Peaches that were more mature by 4 days developed higher flavor but were more stringy in texture. Cravens and Paul (*48*) found that "firm ripe" peaches (requiring 5 to 8 days to ripen to prime eating condition) developed as high a quality as "tree ripe" peaches (2 to 4 days to ripen) when each stage was in prime condition. Peaches picked "hard ripe" (8 to 10 days to ripen) never developed as good a quality as the more mature fruit. From these results it is apparent that peaches do not have to be picked "tree ripe" in order to have very good dessert quality.

On the basis of these results, Haller (*81*) has suggested that good quality ripe peaches might be made available to consumers by picking the fruit at the usual shipping stage of maturity, and then ripening them at the terminal markets before delivery to retail markets, instead of trying to market tree-ripened fruit.

EFFECT OF RIPENING TEMPERATURE

The dessert quality of peaches may be influenced also by the temperature at which they are ripened. Davies, Boyes, and De Villiers (*50, 51, 52*) reported that peaches and nectarines developed better dessert quality when ripened at 65° F. than when ripened at 45°. They found that Peregrine peaches ripened at 45° were insipid and off-flavor but did not develop woolly (mealy) breakdown. Overholser, Morris, and Wooton (*173*) ripened Elberta and J. H. Hale peaches at 75°, 55°, and 40° after stor-

age at 32° for 1 week. The highest dessert quality was developed at 75°, intermediate quality at 55°, and very low quality at 40°. Haller and Harding (*82*) found that peaches ripened with good quality at 60°, 70°, and 80°, but were insipid and off-flavor when ripened at 50°. The peaches failed to ripen when held continuously at 40°, 36°, or 32°, but could be ripened at 70° after short periods at the lower temperatures.

Mallison and Haller (*144*) found that Elberta and Belle peaches held at 40° F. for 7 to 10 days and then ripened at 70° developed poorer dessert quality than those held at 32° and ripened at 70°, or those ripened at 70° without previous exposure to low temperatures. Smith (*194*) observed that Elberta peaches ripened more rapidly at 76° to 77° than at either a lower temperature of 65° or a higher temperature of 90°. The best quality for canning, however, was obtained when the peaches were ripened at 65°, with a relative humidity of 80 to 85 percent. On the other hand, Neubert and Veldhuis (*167*) reported optimum flavor for canning was developed at 75°, as compared with 65°, 85°, and 95°. They observed that the rate of ripening was accelerated by increased temperature and that the color of the canned fruit became progressively deeper yellow as the temperature was increased. Van Blaricom and Musser (*215*) suggested the desirability of ripening peaches for canning at 55° to 65°, which would normally require some refrigeration of the ripening room. They stated that peaches ripened more uniformly at 65° than at higher temperatures, but were lighter in color and not quite so good in flavor. Atkinson (*15*) recommended that peaches for canning be picked when 4 to 6 days from ripening and that they be held at room temperature until 1 to 2 days from ripening. They could then be stored at 31° for a week before final ripening.

The above results and recommendations are not in agreement as to the optimum temperature for ripening peaches. Additional investigations are needed to determine the necessity or desirability of controlling the ripening temperature and to determine the optimum temperature for ripening. Haller (*81*) has suggested the desirability of ripening peaches at the terminal markets before delivery to retail outlets by holding them at prevailing outdoor temperatures. If ripening temperatures markedly affect the dessert quality, it might be desirable to ripen the fruit in special ripening rooms that could be maintained at the optimum temperature.

RESPIRATORY ACTIVITY

Determination of respiratory activity is a measure of the physiological activity of the fruit that might be used as an index to ripening or deterioration. Respiratory activity is also of interest in connection with refrigeration as a measure of the vital heat being developed by the fruit.

Matsumoto (*149*) followed the respiratory activity of peach fruits during their development. He observed that the respiratory

activity decreased greatly during growth, reached a minimum at the period of maximum growth rate, and then increased again as the fruit approached ripeness. Tindale, Huelin, and Trout (*207*) determined the respiratory activity of mature peaches at 32°, 45°, and 55° F., over extended periods. At 32° peaches respired at the rate of 6 to 7 mg. CO_2 per kg.-hr. The rate was 3 to 4 times higher at 45° (20 to 28 mg.), and 6 to 7 times higher at 55° (37 to 42 mg.), than at 32°. At 55° and 45° the respiratory activity rose to a peak as the fruit approached ripeness, and then decreased as the fruit became overripe.

Haller and Harding (*82*) determined the respiratory activity of Carman, Belle, Elberta, and J. H. Hale peaches at temperatures of 32° to 80° F. The rate of CO_2 evolution at 32° varied from 3.8 to 6.2 mg. per kg.-hr. At 80° it ranged from 81 to 141 mg. Haller and Harding point out that higher temperatures increased respiration to a greater extent in peaches than in many other fruits, and the effect was greater at low temperature ranges than at high temperature ranges (Q_{10} of 4.1 at 32° to 50° and 2.2 at 62° to 80°). The ratio of CO_2 to O_2 averaged about 1.1 at all temperatures, indicating that sugars (and some acid) were the primary materials used in respiration. Fisher, Britton, and O'Reilly (*67*) report respiration rates of about 3.5 to 5.0 cc. (7 to 10 mg.) CO_2 per kg.-hr. at 32°, and increased rates of 30 to 47 cc. (60 to 94 mg.) CO_2 per kg.-hr. for peaches held at 70° to 80°. Immature peaches respired at about the same rate as mature fruit.

Claypool and Allen (*43*) determined the respiratory activity of Primrose peaches in 21-, 15-, 10-, 5-, and 2.5-percent concentrations of O_2 at 65° and 40° F. The respiration rates were roughly proportional to the O_2 concentration. At 65° the respiration rates and the differences in rates between O_2 concentrations increased with time, whereas at 40° the rates and differences in rates decreased with time. At 65° the rate in air (21 percent of O_2) was about 27 to 39 mg. CO_2 per kg.-hr., whereas in 2.5 percent O_2 the rate was only 11 to 15 mg. At 40° the corresponding rates were 4.5 to 7.5 mg. in air, and 3.5 to 3.8 mg. in 2.5 percent of O_2.

STORAGE

As pointed out in the section on ripening, at cold-storage temperatures peaches deteriorate rather rapidly in dessert quality and soon lose their ability to ripen even when transferred to room temperatures. Consequently, peaches are seldom stored, and then only for short periods to carry them over a glut in the market, or to extend the handling season for processing. The effects of low temperatures on fruit ripening are also of interest from the standpoint of precooling and refrigeration in transit. The storage quality of peaches is determined largely by their resistance to mealiness and breakdown at low temperatures, whereas the shipping quality is related to resistance to bruising and injury during handling. This is determined largely by firmness of the flesh, toughness of the skin, and rate of ripening.

TEMPERATURE STUDIES

Morris (*162*) observed that storage at 40° and 50° F. retarded ripening but permitted normal changes in peaches so that good quality was attained, whereas at 32° normal ripening and softening was prevented so that fruit ripened to poor quality. There is no indication that Morris transferred the peaches from the cold temperatures to ripening temperatures. Stahl and Cain (*204*) and Stahl and Vaughan (*205*) stated that the optimum storage temperature for four varieties of peaches grown in Florida was 42°. They stated that temperatures below 40° were unsatisfactory because of darkening of the flesh. However, the only temperature below 40° used by them apparently was 37°. Except for the reports that have just been mentioned, all other investigators show that the storage life of peaches is longer at the lower temperatures of 30° to 33°.

Harding and Haller (*89*) held four varieties of peaches at 32°, 36°, 40°, 50°, 60°, 70°, and 80° F. Peaches held at the low temperatures were removed at intervals to room temperature for ripening. Contrary to the findings of Morris (*162*), they found that ripening was abnormal at 50° in that off-flavors developed. They also found that breakdown developed in peaches held too long at the lower temperatures after they were transferred to room temperature for ripening. The breakdown developed sooner if the fruit had been stored at 40° than if stored at 36°, and sooner if stored at 36° than at 32°. The breakdown was described as a water-soaked area radiating into the flesh from around the pit. The affected area became brown with later development of the breakdown. Mealiness and loss of flavor were associated with the disorder. The breakdown was not apparent from external appearances until it became very severe. Later, Harding and Haller (*90*) reported similar results with additional varieties.

The superiority of 32° and 31° F. over somewhat higher temperatures of 34° to 45° has been confirmed by a number of investigators. Smith and Willison (*202*) and Smith (*201*), in Canada, found the storage life of firm mature Elberta peaches was longer at 32° than at 37°. Davies, Boyes, and De Villiers (*50*), in South Africa, reported that earlier tests showed that development of woolliness (mealiness) and breakdown and loss of flavor in Elberta and other varieties of peaches was more rapid at 40° and 35° than at 32°. Further tests indicated that 31° was superior to 34° or 37°. Additional results (*51*) confirmed the superiority of 31° to 37°, 40°, or 45° from the standpoint of dessert quality of ripened fruit, and also as to reduction in breakdown. Woolliness did not develop at 45°, but the fruit became insipid and off-flavor. Huelin, Tindale, and Trout (*115*), in Australia, found that the storage life of seven varieties of peaches was appreciably longer at 32° than at 34°. Williams (*226*), also in Australia, stated that peaches kept better at 32° than at 36°. Krumbholz (*127*), in Germany, reported that peaches lose their ability to ripen when held at 36.5° to 41° (2.5° to 5.0° C.), and he recommended a storage

temperature of 31° to 32° (-0.5° to 0° C). Willison (*228*) found that the storage life of four varieties of peaches was limited by breakdown or loss of ability to ripen when returned to room temperature. He found that the storage life of peaches was appreciably longer at 33° than at 45°.

Fisher and Britton (*66*) found the average storage life of 7 varieties of peaches to be 15.5 days at 32° F., and only 9.5 days at 40°. Overholser and others (*171*), in Washington, compared the storage life of 10 varieties of peaches at 32° and 43°. They found the storage life was longer at 32°, but the edible quality after ripening was better if the fruit had been stored at 43°. Veldhuis and Neubert (*218*), also in Washington, compared the storage of peaches at 31°, 37°, and 45°. They found that the longest storage life was at 31°, and they noted a rapid deterioration in the steam-peeling qualities of fruit stored at 37° and 45°.

O'Reilly (*170*) held four varieties of peaches at 32° and 40° F. He concluded that 32° was the more suitable temperature when peaches were held either in air or in modified atmosphere. Paul and Cravens (*174*) also found that Elberta peaches were best if stored at 32° and ripened at room temperature. They found that the flavor deteriorated rapidly at 50° and 41°.

The results just given clearly show that storage at 31° or 32° F. is superior to higher temperatures of 34° to 50°. There is some indication that storage at 30° results in longer storage life than storage at 32°. Haller and Harding (*82*) found considerable freezing at 30°, but observed that unfrozen fruit at 30° ripened with somewhat better quality than that at 32°. Allen (*6*) stated that storage at 30° was slightly better than at 32° for most varieties of peaches. Later (*9*), he concluded that storage at 31° was better for well-matured peaches than at 32°. There was less reddening at the pit when the fruit was held at 30° or 31° than when held at 32°. Hall (*75, 76*) also found storage at 30° to be somewhat better than at 32°, as there was less wastage and a fresher flavor with fruit from 30° storage.

Davies, Boyes, and De Villiers (*50*) reported that a temperature as low as 29° F. gave better results than 31° with one lot of peaches. Wright (*233*) gives the average freezing temperature for 13 varieties of peaches in a hard (shipping) stage of maturity as 29.4°, with individual fruits of most varieties freezing at about 30°. Storage at temperatures below 30°, therefore, would not be safe, and even storage at 30° would require very close control to avoid freezing. However, the results have indicated that the ability of peaches to ripen at room temperature with good quality generally can be maintained longest by holding them as near their freezing point as possible without freezing. Practically, this would probably be at 31°, as the slight additional benefit from holding at 30° would probably be offset by the greater danger of freezing.

Results of the different investigations just cited are in agreement in showing that peaches placed in cold-storage temperatures (30° to 36° F.) in a hard condition will not become fully ripe at

these temperatures, but must be removed to room temperatures (60° or above) to ripen. At the low storage temperatures the fruit gradually deteriorates in dessert quality, loses its capacity to ripen without becoming mealy or developing breakdown, and finally develops breakdown. The deterioration in dessert quality and the tendency to develop breakdown is most rapid at 36° to 40° and decreases in rate at lower temperatures. Peaches will usually ripen without developing breakdown at temperatures of 45° to 50°, but will ripen with poor quality and off-flavors. Transit temperatures in refrigerator cars are generally in the range (35° to 50°) in which quality deteriorates most rapidly and in which breakdown is most likely to develop. It would be desirable to have more information on the effect of these temperatures for short periods that correspond to the usual transit periods.

The length of the storage life at 32° F. for different varieties of peaches as determined by different investigators is given in table 4. The storage life represents the length of time the peaches

TABLE 4.— *Storage life of different varieties of peaches at 32° F.*[1]

Variety	Storage life	Authority [2]
	Days	
Augbert	21–28	Harding and Haller (*90*).
Belle (Belle of Georgia).	21–28	Do. (*90*).
Carman	14–21	Do. (*90*).
Champion	14–21	Do. (*90*).
Elberta	21–28	Do. (*90*).
Do	10–12	Fisher and Britton (*66*).
Do	14	Willison (*228*).
Do	24 (33°)	Williams (*226*).
Do	10–17 (31°)	Davies, Boyes, and De Villiers (*50, 51, 52*).
Do	10–14	Smith and Willison (*202*).
Do	21–28 (30°)	Allen (*6*).
Do	21–28 (31°)	Veldhuis and Neubert (*218*).
Do	28	Krumbholz (*127*).
Golden Jubilee	21	Fisher and Britton (*66*).
Hiley	14–21	Harding and Haller (*90*).
J. H. Hale	28	Do. (*90*).
Do	12–14	Fisher and Britton (*66*).
Do	25	Williams (*226*).
Do	35–42 (30°)	Allen (*6*).
Late Crawford	28	Harding and Haller (*90*).
Do	42–70	Huelin, Tindale, and Trout (*115*).
Do	63-70	Tindale, Huelin, and Trout (*207*).
Do	35	Williams (*226*).
Rochester	21	Fisher and Britton (*66*).
Do	21	Willison (*228*).
Valiant	14	Fisher and Britton (*66*).
Do	21	Willison (*228*).
Veteran	14	Fisher and Britton (*66*).
Do	17	Do. (*66*).
Vedette	21	Willison (*228*).

[1] Except where other temperatures are given.
[2] Italic numbers in parentheses refer to Literature Cited, p. 92.

could be held at the low temperature and still ripen at room temperature without serious loss of flavor or development of breakdown. Information relative to the storage life of additional varieties, particularly some of the promising new ones, would be desirable.

Chemical changes in peaches during storage at different temperatures were studied by Haller and Harding (*82*). They associated the relatively rapid loss of flavor and the tendency to develop breakdown at the intermediate temperatures of 36° to 50° F. with a relatively rapid loss of acidity. There was no consistent change in dry weight and sugars during storage at the different temperatures.

DELAYED STORAGE

Partial ripening at room temperature (delayed storage) has been shown to affect certain physiological low-temperature disorders of apples, and it might be expected to influence the low-temperature breakdown or mealiness in peaches also. Morris (*163*) held three varieties of peaches at 70° to 90° F. for 12 to 18 hours before storing them at 34° to 36°, but found the delay materially shortened the storage life of the fruit. Davies, Boyes, and De Villiers (*50*), in South Africa, held Elberta peaches for 1, 3, 6, and 9 days at room temperature before storing at 34°. Preripening for 3 days improved the quality as compared with either shorter or longer preripening periods.

With Peregrine peaches delayed 1, 2, and 3 days before storage, woolliness was reduced in proportion to the length of the delay. It was practically eliminated with a delay of 3 days, and very largely controlled with 2 days. In later, more detailed studies (*51*), Peregrine peaches were delayed ½, 1, 1½, 2, 2½, and 3 days at 75° F., and longer periods at 65° and 50° before being stored at 31°, 34°, and 37°, and were postripened at 65° and 45°. Woolliness in peaches stored at 34° and 37° decreased with the length of the delay at 75°, but a delay of 2 to 3 days was required to reduce it to insignificant amounts. A delay of 4 days at 65°, and 8 days at 50°, was required to reduce woolliness to small amounts. Shorter delays at 50° and 65° tended to increase woolliness instead of decreasing it, although the increase was less at 65° than at 50°. Although delay at 50° reduced woolliness, it was unsatisfactory in that the fruit lacked flavor. These results were confirmed in a later report (*52*). Reyneke (*183*), also in South Africa, distinguished three stages of maturity: (1) A hard or green stage in which the fruit is juicy, (2) a firm stage, with the color turning, in which the fruit lacks juiciness, and (3) a tree-ripe, yellow stage in which the fruit is again juicy. He observed that when the fruit was stored at low temperatures in a juiceless stage, it became woolly after storage. Thus, when firm, juiceless fruit was stored immediately, it became woolly; but if preripened for 24 hours, it passed out of the juiceless stage and could then be stored without becoming woolly. On the other hand, green fruit that

was juicy did not become woolly in storage if stored immediately. If delayed 24 hours, it became firm and juiceless; and if stored in this condition, it became woolly. A delay of 48 hours was required for hard, green fruit to pass through the juiceless stage and to become juicy again.

Fisher and Britton (*66*), in Canada, held six varieties of peaches of two stages of maturity at 75° F. for 1 and 2 days before storing them at 32° and 40°. Samples were transferred to 65° at weekly intervals for ripening. Except for the J. H. Hale variety, the delays increased the storage life by reducing mealiness or mealy breakdown. The effect was relatively greater at 40° than at 32°, and increased with the length of the delay. The average life at 40° was 10 days with immediate storage, 19 days with a delay of 1 day, and 21 days with a delay of 2 days. At 32° the corresponding figures were 17 days with immediate storage, 21.5 days with a delay of 1 day, and 26.5 days with a delay of 2 days. The investigators reported that with delay before storage the fruit was juicier and of better flavor when ripe than fruit stored immediately at 32° and 40°.

In a later report, Fisher, Britton, and O'Reilly (*67*) presented results in which the fruit was softened to a specific firmness (10- to 12-pound pressure test with 5/16-inch plunger through skin of cheeks) before storage. At this firmness the fruit was considered to be firm enough for shipment. At packing-house temperatures of 60° to 80° F., Rochester and Vedette peaches required 1 day for mature and 2 days for immature (less mature) fruit to reach this firmness. Elberta and J. H. Hale required 2 to 3 days for mature and 5 or 6 days for immature fruit at 65° to reach this firmness. When Golden Jubilee, Rochester, Vedette, and Valiant peaches were delayed 1 or 2 days before storage, their storage life was extended 1 to 2 weeks. With Veteran there was no benefit from delay, and with Elberta and J. H. Hale the results were inconsistent. On the other hand, Smith (*195*), using Washington-grown Elberta peaches of advanced maturity (pressure test of 5 to 11.5 pounds with 5/16-inch plunger through skin of cheeks), found that they developed better texture and flavor for canning when stored immediately at 31° and postripened than when preripened or delayed 2 or 3 days at room temperature before storage. Veldhuis and Neubert (*218*), also using Washington-grown Elberta peaches, found that the fruit held up longer at 31° when preripened at room temperature for several days before being stored. O'Reilly (*170*) held Cumberland, Golden Jubilee, Halehaven, and Elberta peaches of two stages of maturity at 70° to 80° previous to storage at 32° and 40° for 22 days. He concluded that a delay of 2 to 5 days prior to cold storage was required to prevent a mealy type of storage breakdown. The length of the delay necessary was longer with immature (less mature) than with mature fruit, but even mature fruit benefited from delay.

Although the results just given are rather consistent in showing that partial preripening reduced breakdown during storage, there are a number of phases of the question that need further study before this practice can be applied under commercial con-

ditions in the United States. The question of the relation of picking maturity to juiciness and to the length of the delay necessary needs further study. For peaches that are to be marketed in the fresh state, it is likely that partial preripening might soften them so that they would be very subject to bruising during shipping and handling. This aspect needs investigation. It would certainly favor the development of decay, so that the fruit would arrive at terminal markets showing generally higher percentages of decay and would require re-sorting to remove any decayed fruit.

CONTROLLED-ATMOSPHERE STORAGE

Modification of the concentration of CO_2 and O_2 in the storage atmosphere has been found to retard the development of low-temperature disorders of certain varieties of apples and to extend their storage life. High concentrations of CO_2 during transit have been found to retard decay development of cherries. Investigations have been conducted to determine whether modifications of the atmosphere in storage or transit might have similar effects on peaches.

Thornton (*206*) studied the tolerance of various fruits and vegetables to different concentrations of CO_2. He found that Belle (Belle of Georgia) peaches were injured by a 30-percent concentration of CO_2 for 4 days at 32° and at 39° F. (0° and 4° C.), by 20 percent CO_2 for 4 days at 50° (10°C.), but not by 20 percent for 4 days at 32° and 39°, or by 10 percent at 50°. Injury consisted of skin browning and off-flavors.

Brooks and others (*34*) treated several varieties of peaches with different concentrations of CO_2 from dry ice (solid CO_2), in constant-temperature rooms, small chambers (pony reefers), and standard refrigerator cars. In agreement with Thornton, they found that there was a temperature-time relationship. They indicated that exposure of peaches to 25 percent or more of CO_2 for 1 day at 77° F. had about the same effect on flavor as 2 days at 59°, 3 days at 50° or 4 days at 41°. The flavor of the peaches remained normal if the CO_2 in the air dropped to 25 percent or less by the end of 12 hours, and to 10 percent by 24 hours. Treatment with CO_2 in refrigerator cars checked the development of brown rot and rhizopus rot in inoculated fruit. The retardation in decay was about equivalent to that due to the difference in temperature between the top and bottom of the load in a standard refrigerator car. The CO_2 treatment retarded the softening or ripening of the fruit even more than it retarded decay development.

In a study of the effect of the CO_2 treatments on the composition of the fruit, Miller and Brooks (*158*) found that the sugars and acid-hydrolyzable polysaccharides were not affected by the CO_2 treatments, even when the treatments were severe enough to cause overripe (off-) flavors. In further tests, Brooks, Bratley, and McColloch (*31*) observed that J. H. Hale peaches were more tolerant of CO_2 than some other varieties. Their results indicated the J. H. Hale peaches could be exposed to 50-percent concentration of

CO_2 for 40 hours at 59° F. without loss of flavor. There was some indication that the tolerance to CO_2 might differ with the conditions under which the fruit was grown.

In still later shipping tests with peaches in both rail refrigerator cars and in trucks, Brooks, Schomer, and Bratley (*35*) found that 400 to 500 pounds of solid CO_2 per truck, or 700 to 800 pounds per refrigerator car, was necesary to obtain a sufficiently high concentration of CO_2 in the air. By this means CO_2 concentrations as high as 30 percent were obtained for short periods. The results of several shipments indicated that CO_2 treatments maintained the firmness of the fruit and in most cases definitely decreased decay, especially in the top layers of the loads.

Huelin, Tindale, and Trout (*115*) stored Late Crawford and other varieties grown in Australia in 4- to 15-percent concentrations of CO_2 at 32° and 34° F. In 15 percent CO_2 there was definite injury consisting of slight discoloration and off-flavors. Maximum storage life was obtained in 8 to 10 percent CO_2, which generally increased storage life by about 50 percent in all varieties. Storage life of Late Crawford is given as 10 to 13 weeks in CO_2 at 32°, as compared with 6 to 9 weeks in air. In a later report, Huelin and Tindale (*114*) observed that CO_2 increased storage life only when the fruit was picked in a firm stage of maturity (pressure test of 15 pounds or more with 5/16-inch plunger), whereas the storage life of softer peaches (pressure test of 10 pounds or less) was unaffected or decreased by CO_2 storage. Storage in 8 to 10 percent CO_2 for 4 weeks, followed by air storage at 32°, was generally as satisfactory as continuous storage in CO_2.

Tindale, Huelin, and Trout (*207*) found that storage in 8 to 10 percent CO_2 at 32° F. did not reduce brown rot compared with air storage. Allen and Smock (*10*) and Allen (*7*) held J. H. Hale (pressure test 10.5 pounds) and firm-ripe Elberta (pressure test 3.0 pounds) peaches 6 days at 45° F. and 10 days at 32°, in air and in 15 percent CO_2. The CO_2 treatment appreciably retarded ripening, with no adverse effect on flavor. In a later study, Allen (*8*) held Levi cling peaches at 45° for 5 to 10 days in air, in 11 percent CO_2, and in 30 percent CO_2 that diminished to 5 percent. He noted that the treated fruit was firmer (pressure test 9.0 and 8.7 pounds. as compared with 6.9 pounds), greener (60 and 50 percent greenish, as compared with 100 percent yellow), and took longer to ripen. In a still later report, (*9*) Allen stated that at 32° there was little difference between fruit held in 10 and 15 percent CO_2 and that held in air. At 45° softening and coloring were retarded somewhat by CO_2 treatment, but internal breakdown developed, so that the storage life was not appreciably extended.

Fisher and Britton (*66*) treated Vedette, Veteran, and Valiant peaches with 23 to 37 percent CO_2 for 2 and 4 days at 65° F. The CO_2 treatments slowed softening during treatment but did not extend the time required for the fruit to become overripe after treatment. Off-flavors and breakdown developed in all of the varieties treated for 4 days, and breakdown occurred in one of the varieties treated only 2 days. Storage of Vedette, Valiant, and

Rochester peaches in 7.5 percent CO_2 at 40° for 1 and 2 weeks resulted in off-flavors and mealiness. The storage life of the fruit was extended slightly as compared with 40° storage in air, but was less than 32° storage in air. In a later report, Fisher, Britton, and O'Reilly (*67*) found that storage of J. H. Hale or Rochester peaches in 5 to 9 percent CO_2 at 32° did not delay the appearance of breakdown or prolong the life of the fruit after removal from storage. Also, the skin of the Rochester peaches was injured.

Gerhardt, Smith, and English (*72*) and Smith, Gerhardt, and English (*196*) stored Elberta and J. H. Hale peaches at 31° F. in air and at 36° and 45° in 0, 5, 10, and 20 percent CO_2 for 5 and 10 days. Both varieties were tolerant to CO_2 concentrations as high as 20 percent for 10 days at 45°. CO_2 at 10 and 20 percent was effective in retarding color development and softening. Storage in 20 percent CO_2 at 45° was as good as storage in air at 36°, and storage in 20 percent CO_2 at 36° was equivalent to air storage at 31°. There was no apparent residual effect of the CO_2 during ripening after storage, and no adverse effect on flavor was noted.

Hall (*75, 76*) stored two varieties of peaches in 5 and 10 percent CO_2 at 32° F. He found that storage in CO_2 was unsatisfactory, as it resulted in poor texture and off-flavors.

O'Reilly (*170*) stored four varieties of peaches at 32° and 40° F. in the following respective percentages of CO_2 and O_2: 2 and 2, 2 and 5, 5 and 2, 10 and 2, 10 and 5, 10 and 11, and normal air (0.02 and 21). Off-flavors developed in 10 percent CO_2. He found that although off-flavors did not develop in lower concentrations of CO_2 and O_2 (2 to 5 percent), the storage life was not appreciably extended as compared with storage in normal air.

The effect of CO_2 on the fruit is of interest in connection with prepackaging when the fruit is overwrapped with films of which most are impermeable, or nearly so, to CO_2. Hruschka and Kaufman (*112, 113*) reported that appreciable concentrations of CO_2 accumulated within packages of peaches overwrapped with cellophane (MSAT and LSAT types), and to a less extent in cellulose acetate. Similar results were obtained by Schomer and Lieberman (*189*). They found that an accumulation of 10.4 percent CO_2 in 4 days at room temperature caused off-flavors in most of the fruit.

Hruschka (*111*) wrapped peaches with films of different porosity and found that a film perforated to pass 50 cc. of air per square inch, under a pressure of 20 ounces per square inch, in 188 seconds permitted as much as 9.4 percent of CO_2 to accumulate in 1 day at room temperature, and that noticeable off-flavors developed that became progressively worse with time.

In general, the results have shown that softening (ripening) and color development have been retarded somewhat when the atmosphere surrounding the fruit contained as much as 10 percent CO_2 at temperatures of 36° F. and above (Allen and Smock (*10*), Brooks, Bratley, and McColloch (*31*), Brooks and others (*34*), Allen (*8, 9*), Fisher and Britton (*66*), and Gerhardt, Smith, and English (*72*)). Where CO_2 has had no appreciable effect (Gerhardt, Smith, and English (*72*), Fisher, Britton, and O'Reilly

(*67*)) the concentration generally has been less than 10 percent, or the temperature has been below 36°.

CO_2 in the storage atmosphere has caused off-flavors to develop in the fruit, the extent to which they develop depending on the concentrations of CO_2, the length of exposure, and the temperature. Varietal differences in susceptibility may also be a factor. The minimum concentration, time, and temperature at which off-flavors develop has not been definitely established. Thus, off-flavors were reported with exposure to 10 percent of CO_2 at 32° to 40° F. by O'Reilly (*170*), Hall (*75*), and Fisher and Britton (*66*), but no off-flavors were reported by Allen and Smock (*10*) at such higher concentrations as 15 percent for 10 days at 32°, or by Gerhardt, Smith, and English (*72*) at 20 percent for 10 days at 36°. The concentrations of CO_2 at temperatures that were high enough to retard ripening or decay development were generally also in the range that caused off-flavors or injury. There appears to be little possibility, therefore, of benefit from the use of CO_2 in the atmosphere around peaches.

In some instances the CO_2 in the atmosphere was increased by vaporizing solid CO_2 (Brooks and others (*34*) and Brooks, Bratley, and McColloch (*31*)). In other instances the fruit was in air-tight chambers, and the CO_2 evolved by respiration was allowed to accumulate to the desired concentration. When the latter method is used, the O_2 in the atmosphere is correspondingly reduced, so that the sum of the CO_2 and O_2 concentrations approximates 21 percent. Changes in the fruit have usually been attributed to the accumulation of CO_2, although the reduced O_2 supply might also have an effect. In the studies by O'Reilly (*170*) the O_2 was reduced without a corresponding increase in CO_2. In these studies there was no appreciable effect of the reduced O_2 concentration on the rate of ripening of the fruit or the development of off-flavors. Claypool and Allen (*43*) held Primrose peaches for 10 days at 65° and 40° F. in different levels of O_2 concentration, with the CO_2 concentration remaining normal (0.02 percent). At 65° in air (21 percent O_2) the peaches colored and ripened in 10 days. Ripening remained at the same rate when the concentration of O_2 was reduced to 15 percent, but it decreased at lower concentrations, with practically no ripening in 2.5 percent O_2. Claypool and Allen observed no adverse effects on flavor from reduced O_2 concentrations.

Miller and Brooks (*158*) analyzed Belle peaches for sugars and acid-hydrolyzable polysaccharides following treatment with 35 to 47 percent of CO_2 for 1 day at 68° and 59° F., and 2 days at 50°, 41°, and 32°. Treatment with CO_2 had no effect on the components determined, although the treatments at the higher temperatures (59° and 68°) resulted in overripe (off-) flavors.

PRECOOLING

Because peaches are harvested in the summer when prevailing outside temperatures are high and since they ripen rapidly and

soon become very soft at these high temperatures, it is very important that they be cooled as rapidly as possible in order to keep them firm enough for handling without bruising during their marketing period. Peaches are very subject to decay during ripening, and the development of decay is much more rapid at high temperatures (see pp. 85, 90). Therefore, precooling and refrigeration in transit are used to retard softening and also as a means of retarding decay development. Although decay on peaches arriving at terminal markets may be less because of refrigeration in transit than on peaches not refrigerated, this does not mean that refrigeration has controlled the decay. Refrigeration does not kill the decay organisms, but only retards their development. Upon arrival of peaches at the markets, the organisms renew their development—and the development continues during subsequent ripening of the fruit (see pp. 85 and 90).

A number of methods of precooling peaches have been used. These may consist of (1) circulating the car air through the cooling coils of a mechanical refrigerating unit mounted on a truck (portable precoolers), (2) circulating the car air through the bunker ice (to which salt is usually added at the rate of 3 to 5 percent of the weight of ice in the bunkers), and (3) cooling the fruit by a flood of ice water (to which a germicide may be added).

Precooling by circulating the car air through the bunker ice may be accomplished by temporarily installing fans in the upper bunker opening, or in the case of fan-type cars by using the fans permanently installed in the cars. In the latter case, an electric motor or gasoline engine is attached to the fan shaft on the outside of the car. With either of these methods it is customary to reverse the normal direction of air flow due to convection currents so that the top of the load tends to cool as fast as or faster than the bottom of the load.

Excessive breakdown (woolliness) (*1*) in South African peaches during two seasons (1934–35 and 1935–36) was attributed to especially rapid precooling. However, an experimental test by Davies, Boyes, and De Villiers (*50, 51*) indicated that rapid precooling tended to retard rather than to increase breakdown.

Newell and Lloyd (*169*) precooled Illinois peaches by means of fans, in the upper bunker openings, that did not reverse the normal direction of air flow. Use of the fans reduced the temperature of the fruit from 80° F. to 50° to 60° in 20 hours. As compared with loads not precooled, temperatures in the precooled loads averaged somewhat lower, and there was less difference between temperatures in the top and bottom of the load.

Using a portable-type precooler (mechanical refrigerating unit on a truck) Mallison and Wiant (*145*), working in Georgia, reduced the temperature of a carload of Hiley peaches by 20° to 25° F. in 2½ hours. They estimated that this extended the marketing period by about 1½ days. In a test with Early Rose peaches (*145*), the drop in temperature was 30° to 33° in 3½ hours. In this test shipment from Georgia, the temperature remained about 10° to 20° lower in the precooled car than in the car not precooled.

In a later report, Mallison, Bratley, and Wiant (*143*) observed that precooling was most beneficial to fruit in the top layer of the load, where precooling reduced softening of the fruit to nearly half as much as it would have been without precooling. They suggested that considerable ripening in transit may be desirable with hard fruit in the early stages of maturity. In that case precooling may not be desirable. They stated that precooling may be of value also in reducing losses from decay.

Hienton, Fawcett, and Gaylord (*106*) found that peaches in refrigerator cars cooled as much in 4 hours when packed in ventilated baskets and precooled by circulating air through the bunker ice as they did in 34 hours when packed in nonventilated baskets and not precooled. Later, Hienton and Fawcett (*104*) reported that the rate of cooling during precooling varied from 2.5° to 3.9° F. per hour, depending on the amount of ventilation in the baskets. They reported (*105*) cooling of peaches in the top layer to be as much as 30° in 8 hours by forced circulation of air through bunker ice to which 400 pounds of salt had been added. The development and spread of brown rot and the rate of ripening of the fruit was greatly reduced in peaches that were precooled to 40° or less. Lloyd (*131*), in Illinois, also determined the rate of cooling of peaches during precooling with portable precoolers. as well as with bunker ice, in relation to the amount of ventilation in the baskets. The average rate of cooling for seven cars was 3.9° per hour for peaches in ventilated baskets, and 2.7° per hour in nonventilated baskets. These results are in very good agreement with those reported by Hienton and Fawcett (*104*).

Haller (*77*) found that the average commodity temperature in carloads of Maryland peaches was reduced 21° F. in 5 hours (4.2° per hour) by circulating the air through the bunker ice by means of fans in the upper bunker openings. He estimated that ice meltage was 310 pounds per degree of cooling. This figure was more than twice the theoretical amount required to remove the field heat from a load (assuming no transfer of heat through the car walls and disregarding the heat of respiration). At this rate complete melting of full bunkers of ice would cool the load about 30°. The rate of cooling would become slower as the surface area of the ice decreases and as the temperature of the load is reduced. Consequently, Haller considered a reduction in the temperature of the load by about 25° as much as would be practical without replenishing the ice in the bunkers. To lower the temperature 25° would require 6 to 7 hours of precooling. Haller (*80*) found that the rate for cooling wrapped Colorado peaches in lug boxes was 20° in 9 hours (2.2° per hour) by means of fans in the top bunker openings circulating air through the bunker ice (with 3 percent of salt). Somewhat faster cooling was obtained (about 2.8° per hour) when fans (Preco) permanently installed under the floor racks were used instead of the bunker fans. He observed that if salt was added when the cars were re-iced in transit in addition to when they were precooled, the temperatures at the bottom-bunker positions fell to dangerously near the freezing point.

Fawcett and Burkholder (*65*) also used Preco fans for precooling with bunker ice. They obtained cooling of 9° to 15° F. in 5 hours, depending on the amount of ventilation of the package. Additional temperature records during precooling with Preco fans were obtained by Redit, Haller, and Kaufman (*182*) with South Carolina peaches in ventilated bushel baskets and wirebound (Spartan) bushel boxes. The average temperature of the fruit in three carloads of peaches packed in bushel baskets dropped about 22° to 24° in 12 hours following loading in cars not precooled, and about 29.5° in 12 hours, including 7 hours of precooling, in a precooled car. In cars loaded with peaches in Spartan boxes, the fruit temperature dropped 26° in 12 hours without precooling, and 37° in 12 hours, including 7 hours of precooling, in a precooled car. It was observed in these tests that although precooling appreciably hastened the drop in temperature, the cooling was rather rapid even in the cars that were not precooled when loaded only three layers high. The difference in transit temperatures between the precooled loads and those not precooled was not sufficient to measurably affect the ripeness of the fruit on arrival at the terminal market.

More rapid precooling has been obtained by flooding peaches with ice-cooled water (hydrocooling). In this method the fruit is packed but not lidded, and the ice water is pumped over the fruit and allowed to flood through the shipping container. Tests with commercial equipment (Stericooler) designed for this purpose have been conducted in Michigan. Cardinell and Mitchell (*39*), using this method, reported that peaches were cooled from 80° to 45° F. (a drop of 35°) in 15 minutes, but in test runs peaches were cooled from 56° to 38° (a drop of only 18°) in 15 minutes. Barr and Slade (*18*) reported cooling peaches by this method from 83° to 35° (a drop of 48°) in 35 minutes. They stated that a drop of 40° can usually be obtained in a 20- to 25-minute treatment.

Cravens and Cardinell (*46*) reported on replies by retailers and consumers to questionnaires on the condition of peaches from Michigan. The replies indicated no differences in ripeness, bruising, or decay between peaches that were "stericooled" and those that were not precooled (and sometimes not refrigerated in transit). Cardinell and Barr (*38*) gave the average drop in temperature by hydrocooling for the 1948 season as about 40° F. This precooling reduced ice consumption in transit of peaches to New York by 459 pounds per car. These investigators estimated the cost of hydrocooling was about 15 cents per bushel, with a breakdown of 6 cents for ice, 1 cent for extra power and labor, and 8 cents for maintenance, depreciation, and interest. Link and Pancoast (*130*) used this method for precooling peaches for canning before storage. They stated that about ½ pound of ice per pound of fruit was required to cool peaches from 80° to 40°.

Precooling with cold water is much more rapid than with cold air, but a large unit is necessary to provide sufficient capacity not to slow down the packing operations. A machine 8 feet wide by

25 feet long is required to cool 200 bushels per hour with only a 15-minute exposure of the fruit to the cold water (*39*).

TRANSPORTATION

BY TRUCK

In hauling peaches, trucks are used primarily for short runs. Although these trucks are usually refrigerated, the effectiveness of the refrigeration in peach shipments has not been investigated. With short hauls of 24 hours or less there is little need for refrigeration unless the peaches are of advanced maturity or ripeness or are especially subject to decay. Vandermark (*216*) has reported on truck shipments in which the top of the load was covered with a layer of snow ice blown over the load to a depth of approximately 6 inches. No temperature records or detailed data on the condition of the fruit were presented, but it was indicated that ripening and decay were retarded and that there was less bruising. It was stated that the wetting of the baskets and fruit was not objectionable to the receivers.

BY RAIL

REFRIGERATION IN TRANSIT

The rate of cooling in transit, as influenced by the type of package and amount of ventilation in the packages, is discussed under Packaging (p. 28). The effect of precooling on transit temperatures has already been discussed. The influence of methods of loading and type of refrigeration in transit on the temperature and condition of the fruit in rail shipments is considered here.

Newell and Lloyd (*169*) found that peaches packed in unventilated bushel baskets at 85° to 90° F. when loaded into pre-iced cars and shipped under standard refrigeration had cooled to 55° at the top of the load near the doorway and to 40° at the bottom-bunker positions 50 hours after loading.

Haller (*80*) found that cooling of wrapped Colorado peaches packed in lug boxes was slower than reported by Newell and Lloyd for peaches not wrapped and in unventilated baskets. The average drop in temperature as reported by Haller (*80*) was only 20° in 3 days for the Colorado peaches loaded in a standard (end-bunker) car that was pre-iced and shipped under standard refrigeration. Under these conditions the temperatures at the bottom of the load were about 10° lower than at the top of the load. The rate of cooling in the top of the load was more rapid in a fan car than in a standard (nonfan) car. Top temperatures were nearly as low after 1 day in a fan car as after 3 days in a nonfan car. There was no appreciable difference in the rate of cooling in the bottom of the load between fan and nonfan cars. The addition of 3 percent of salt to the ice lowered the top commodity temperatures only 2° to 3°, and in a fan car that was precooled the addition

of salt resulted in bottom-bunker temperatures dangerously near the freezing point of peaches. A car with overhead bunkers had somewhat lower temperatures in the top of the load than standard (end-bunker) cars, but the commodity temperatures in the overhead bunker car were not lowered as rapidly as in fan cars.

Redit, Haller, and Kaufman (*182*) found that cooling was relatively rapid in peaches shipped from South Carolina that were packed without wraps in ventilated bushel baskets or bushel boxes, loaded only three layers high, and shipped under standard refrigeration with 5 percent of salt at initial re-icing. Commodity temperatures of 80° to 90° F. at time of loading cooled to below 50° within 24 hours, even without precooling and even in nonfan cars. Under these conditions the use of fan cars did not appreciably increase the average rate of cooling, but it did result in more uniform cooling in the top and bottom of the loads. Precooling with the Preco fans hastened cooling somewhat, but the benefits from precooling were less than had been reported previously (*80*). Haller and others (*86*) found that when fan cars were used, peaches in vented bushel baskets could be loaded four layers high instead of three layers, with practically no reduction in the rate of cooling. Breakiron and Hoecker (*27*) showed that the percentage of baskets broken was no greater in four-high loads than in three-high loads. They pointed out that if four-high loads were adopted for fan cars there would be a saving to the shipper in charges for refrigeration, and also that reduced freight rates should be possible.

SHRINKAGE IN TRANSIT

Terminal-market inspections have sometimes shown a higher percentage of peaches that did not come up to the minimum size than shipping-point inspections on the same fruit. That this might be due to shrinkage in transit was indicated in studies reported by Mallison and Bratley (*142*). They found that Hiley peaches shipped in vented half-bushel baskets lost about 5 percent in weight and shrank about 1/32 of an inch in least diameter during transit from Georgia to New York. The shrinkage was greater in top-layer fruit than in bottom-layer fruit. Heckman (*99*) reported that the loss in weight during transit of peaches shipped from Colorado was 2 to 3 times as much in peaches picked at the standard shipping maturity as in those picked at an advanced stage of maturity described as firm ripe.

LOADING AND BREAKAGE

In addition to losses from decay and ripening in transit, considerable loss may result from shifting of the load and breakage of containers. Breakage varies with the type of package and method of loading.

Lindley (*129*) reported very low breakage in 38 cars of peaches packed in lugs that were loaded crosswise of the car instead of lengthwise, with vertical sticks between the stacks. Breakiron (*26*) also reported less breakage of lugs when they were loaded

crosswise of the car (42.2 broken packages per car) than when loaded lengthwise (54.4 broken packages per car). He reported even greater reduction in breakage (to only 11.9 packages per car) when a Hoak load was used, but the rate of cooling was considerably reduced. In the Hoak-type load, upright stakes are used to separate the stacks.

Bushel baskets of peaches are usually loaded three layers high. Records obtained by Breakiron (*26*) indicated slightly less breakage in bushel-basket loads that were loaded four layers high (17.9 broken baskets per car) than in those loaded only three layers high (23.5 baskets per car). When there was only a partial fourth layer, breakage was increased to 38.2 packages per car. Half-bushel baskets are usually loaded four layers high, or with a partial fifth layer, and only a few with five complete layers. Breakiron (*26*) found that breakage was less with five complete layers (32 packages per car) than with four layers (47.4 packages per car). A partial fifth layer increased breakage to 53.1 packages per car.

In the standard end-to-end offset load, the baskets in one of the upper layers in each bunker stack are supported only partially by the baskets underneath. Additional support comes from leaning against the bunker walls. In case the load shifts away from the bunker, such baskets tend to drop out of position, become broken, and spill their contents. In loading tests with peaches, Winklepleck (*231*) reported that this could be largely prevented by placing 1- by 6-inch boards on each layer at the bunker to support the offset baskets. The boards were held in place by nailing them to 2- by 4-inch uprights, or preferably by nailing strips of reinforced paper to the boards and extending the paper a short distance back into the load.

SHIPPING QUALITY OF VARIETIES

Variety is also a factor in the transportation of peaches. Whether a variety is a good shipper depends on its firmness when mature, the rate at which it softens, and how soft it becomes as it ripens. Its susceptibility to decay may also be a factor. One reason for the popularity of the Elberta variety is its excellent shipping quality. No systematic studies have been made of the shipping qualities of different varieties, but they have been rated for shipping quality on the basis of general commercial experience.

A number of peach varieties developed in New Jersey are described by Blake and Edgerton (*22*). The report includes observations on the shipping quality of some varieties. Savage (*188*) has described some of the newer varieties grown in Georgia, and has included observations on their shipping quality. Dorsey (*59*) had a number of peach investigators rate the shipping quality of 20 peach varieties. On the basis of these and a few other reports the varieties are rated as follows (authority in parentheses): [15]

[15] See footnote 4, p. 1.

Very Good.—J. H. Hale (*59*), Rio Oso Gem (*59*), and Triogem (*22*).

Good.—Dixigem (*188, 221*), Dixired (*59, 221*), Early Elberta (*59*), Elberta (*59*), Erly-Red-Fre (*59*), Fair Beauty (*59*), Fairhaven (*59*), Fireglow (*22*), Goldeneast (*22*), Halehaven (*62*), Jerseyland (*59*), July (Burbank) Elberta (*59*), Newday (*22*), Redelberta (*59*), Redhaven (*59, 188*), Redrose (*22*), Rosebud (*22*), Southland (*59, 188, 221*), Sullivan Elberta (*188*), Sunhigh (*22*), Triogem (*57, 62*), and White Hale (*22*).

Fair.—Belle (*59*), Dixired (*188*), Fisher (*59*), Goldeneast (*62*), Golden Jubilee (*22, 59, 188*), Halehaven (*59, 188*), Oriole (*22*), South Haven (*59*), Summercrest (*22, 62*), and Triogem (*188*).

Poor.—Carman (*59*), Marigold (*22*), and Mayflower (*59*).

MARKETING

Relatively little work has been done on the influence of handling practices through wholesale and retail marketing channels on the quality of peaches. Cravens and Paul (*48*) determined the time lapse for different phases of marketing of Michigan peaches, from the packing house to the consumer. The total time varied from 2 to 12 days, with an average of 4½ days, to reach the consumer. Consumers kept peaches an average of 3½ days, making an average total time from harvest to consumption of 8 days for 17 shipments of Michigan peaches.

In a survey by Hartmans and Cravens (*91*) it was found that, out of 2,347 bushels handled in a retail market, 944 bushels were sold by the bushel, 892 bushels were sold by the pound, and 511 bushels, representing 22 percent of the total, were lost through waste (bruising, decay, and other factors). Bruising increased from 25 percent on arrival at retail stores to 70 percent after 4 days in the stores. Most of the increase in bruising was due to customers' testing for ripeness by squeezing. Decay increased from none on arrival at stores to 5 percent after 2 days.

To determine the best method of holding peaches during marketing, Brasher and others (*24*) held peaches, picked at shipping maturity, at room temperature (77° F.), in a refrigerator (40°), and packed in ice (34°). The peaches improved most in palatability and ascorbic acid content under room-temperature conditions. Similar tests by Hivon and others (*109*) also indicated room-temperature holding as preferable to holding in cracked ice. Firm to fully mature (ripe) peaches were edible for 7½ days at room-temperature with very little loss of sugars or ascorbic acid. Ascorbic acid content was reduced about 50 percent when peaches were packed in ice for 21 days. However, the peaches packed in ice were somewhat more palatable after 14 to 21 days than after 8½ days at room temperature.

Bratley (*25*) found that the temperature of peaches from cold storage rose 4° to 7° F. during a prepackaging operation. When

returned to cold storage after prepackaging, cooling was slow, only about 1° in 6 hours. Temperature rose about 1° per hour during trucking and holding in retail stores at 70° to 80°.

CONSUMER PREFERENCE

Although consumer-preference studies are primarily concerned with the economics of marketing, which is outside the field of this review, they are of interest in indicating the importance of certain operations covered by this review.

A number of studies have been made in recent years comparing tree-ripened peaches with those picked at a shipping stage of maturity. Merrill (*151*) observed that when firm (unripe) peaches and tree-ripe peaches were displayed at the same time, there was practically no sale of the firm peaches as long as the tree-ripe fruit was available. In a later report (*154*) he indicated that firm-ripe peaches outsold less mature (unripe) fruit, even though priced 1 cent a pound higher. Rummell (*187*) also stated that consumers were willing to pay a premium for tree-ripe peaches. He found that green (unripe) peaches were bought only after the ripe ones had been sold.

Hauck (*92*) found that firm-ripe to soft-ripe peaches outsold hard to firm peaches in the proportion of 4½ to 1 when priced the same, and even outsold them at 2½ to 1 when the ripe peaches were priced at 17 cents and the hard peaches at 12 cents. Similar results were obtained by Hartmans and Cravens (*91*), who found that the sales of soft (ripe) peaches were double the sales of hard peaches. The sale of peaches of excellent appearance was about double the sale of fruit of the same ripeness but of only fair appearance. Peaches that combined both a ripe condition and an excellent appearance sold about six times as fast as hard peaches of only fair appearance. Results obtained by Baker (*17*) give further evidence of the preference for tree-ripe fruit. He indicates that full-ripe peaches at 13 cents per pound sold four times as fast as "green-ripe" (unripe) peaches at 10 cents per pound.

These results show a very strong consumer preference for tree-ripened peaches as compared with fruit picked at a shipping stage of maturity and marketed while still unripe. They do not show that tree-ripe peaches would sell any faster than peaches picked "shipping mature" and ripened before being offered for sale. It is apparent that consumers want ripe peaches, but it may be that "shipping mature" peaches would sell equally well if first ripened. Haller (*81*) has pointed out the practical difficulty of shipping a large volume of tree-ripe peaches, particularly in the Central and Eastern States, where baskets are largely used. He has suggested that equally favorable consumer response might be obtained by picking and shipping the fruit in the usual firm to hard condition and ripening it in the terminal markets before offering it for sale. A study of the consumer response to tree-ripened fruit as compared with peaches that were ripened after harvest would be desirable.

The desirability of prepackaging peaches has not been conclusively shown by consumer-reaction studies. Merrill (*151*) indicated that bulk peaches sold much faster than those prepackaged in 2½-pound units. Rummell (*187*) stated that consumers did not want small peaches, even when prepackaged in cellophane-window packages. On the other hand Baker (*17*) found a slight preference by consumers for prepackaged peaches as compared with bulk fruit, even though the prepackaged peaches sold at a 1 cent premium. The difference became more marked after the bulk peaches had been picked over.

Response to questionnaires, as reported by Cravens and Mauch (*47*), indicated that 81 percent of the consumers reported wastage due to decay in Michigan peaches in the 1946 and 1947 seasons. Wastage caused by worms was reported by 16 to 19 percent. Nearly 50 percent of the consumers complained of the peaches being too green, as compared with 13 to 20 percent who complained of rots. Only 7 percent complained of bruising.

MARKET DISEASES AND DISORDERS

Spoilage in peaches on the market and in the hands of consumers may be due to a number of causes, such as immaturity, bruising, breakdown, insect injury, and decay.

IMMATURITY

Peaches that are picked too early ripen with a tough, rubbery texture, are lacking in flavor, and tend to shrivel excessively. Although immature peaches are not permitted under U. S. grade standards, there is no very satisfactory index by which immature peaches can be distinguished from mature (see p. 25). Consequently, a small percentage of immature peaches may be shipped. A larger percentage of fruit that is considered barely mature and which ripens with only mediocre quality undoubtedly gets by. There seems to be no measure of the loss from such fruit sold to the consumer, and the loss to the shipper would come from reduced demand and lower prices for subsequent offerings. That it may be a very serious factor is indicated by the survey of Cravens and Mauch (*47*), in which it was found that nearly 50 percent of the consumers complained of peaches being too green. By "too green" they probably mean in part immature, although the fruit might be of satisfactory maturity but not as ripe as desired.

BRUISING AND OVERRIPENESS

Peaches become very subject to bruising as they approach a ripe condition. Overripeness is not much of a factor in the marketing of peaches as they would usually show excessive bruising and would be discarded before they become overripe. The extreme susceptibility of ripe peaches to bruising and the relation of various handling practices to bruising are discussed on page 27.

INSECT INJURY

Wormy peaches, caused by infestations of the plum curculio, oriental fruit moth, or peach twig borer, are sometimes found on the market. Infestation by these insects occurs in the orchard. Their control is an orchard-spraying problem that will not be discussed in this publication. Injury from these sources as found on the market is described by Rose and others (*185*).

COLD-STORAGE BREAKDOWN

Davies, Boyes, and De Villiers (*50*) described a woolly (mealy) type of breakdown in peaches shipped from South Africa to England. It was considered to be the most serious type of disorder in such shipments. This type of breakdown occurred in the Peregrine and certain other varieties. In Elberta peaches a different type of breakdown occurred. The flesh around the pit became watery and later turned brown, with the discoloration extending out from the pit. Haller and Harding (*82*) and Harding and Haller (*90*) found breakdown of the type described by Davies and others for Elberta to occur in Elberta and several other varieties when held too long at low temperatures. Willison (*228*) described two types of low-temperature breakdown in different varieties. One type, similar to that described by Haller and Harding (*82*), occurred most frequently in Elberta. In other varieties a diffuse or invasive type occurred, starting near the skin as minute bubbles with pink discoloration that turned brown. The aeration and mealiness diffused inward from the skin, and the fruit became spongy and appeared dead. The two types of breakdown seem to be due to the same causes, and they apparently are different varietal responses to the same disorder. The factors influencing the development of breakdown are discussed under storage and temperature relations of peaches (p. 45).

Breakdown does not seem to be an important cause of spoilage in domestic markets. Very few of the peaches sold as fresh fruit go into storage, and the period in transit is not long enough for breakdown to occur. Breakdown of the type that occurs in Elberta is not visible externally until it becomes very severe, and usually it would not be discovered until the fruit is cut by the consumer.

FUNGUS AND BACTERIAL DISEASES

KINDS

Rose and others (*185*) described and illustrated the principal disorders found in peaches on the market. The primary cause of spoilage in peaches is decay caused by fungi. The organisms (listed by Rose and others) that cause rots and blemishes of peaches are: Green mold rot (*Alternaria* sp.), bitter rot, or anthracnose (*Glomerella* sp.), black mold rot (*Aspergillus niger* Tiegh.), blue mold rot (*Penicillium* sp.), brown rot (*Monilinia fructicola* (Wint.) Honey), California blight (*Coryneum beije-*

rinckii Oud.), cladosporium rot, or green mold rot (*Cladosporium* sp.), gray mold rot (*Botrytis* sp.), leaf curl (*Taphrina deformans* (Berk.) Tul.), powdery mildew (*Sphaerotheca pannosa* (Wallr.) Lev.), rhizopus rot (*Rhizopus nigricans* Fr.), rust (*Transzschelia pruni-spinosae discolor* Dunegan and *T. pruni-spinosae typica* Dunegan), and scab (*Cladosporium carpophilum* Thuem.). They also list bacterial spot caused by the bacterium *Xanthomonas pruni* (E. F. Sm.) Dows.

Wei (*220*) listed and described 14 diseases found on peaches in the Chengtu (China) market. He described *Rhizopus* (*R. nigricans* and *R. articarpa*) as causing serious damage, *Glocosporium serotinum* E. & E. as causing serious damage (as much as 30 percent), *Aspergillus luchuensis* Inui as common and destructive, and *Botrytis cinerea* Pers. and *Cephalothecium roseum* Cda. as causing as much as 10 percent rot at times. He also listed as present: *Alternaria tenuis* Nees, *Aspergillus versicolor* Zukal., *Caldosporium* (probably *Cladosporium*) *carpophilum* Thm., *Macrophoma Kuwatsukaii* Hara, *Penicillium chloro-leucon* Biourge, *Phomo* sp., and *Phomopsis amygdalina* Canonaco. He does not indicate that *Monilinia fructicola* (brown rot) occurred there.

Many of the blemishes are primarily caused by orchard diseases (California blight, leaf curl, rust, and scab) and are found on the market only because such affected fruit was not culled out by the graders. These blemishes are of little or no economic importance on the market and will not be discussed further in this publication. Other diseases, such as brown rot and bitter rot, may occur in the orchard, but many infections caused by them do not develop until the fruit is marketed. Spores of rhizopus rot, blue mold, green mold, and gray mold are almost universally present in the atmosphere. Inoculation of the fruit with such organisms may occur in the orchard, but it is more likely to occur after harvest.

ECONOMIC IMPORTANCE

Brown rot and rhizopus rot are by far the most important rots of peaches. In an analysis of inspection certificates of peaches unloaded at the New York market over a period of 8 years, Wiant and Bratley (*224*) found that decay was recorded in 50 percent of the cars. In these cars an average of 3.8 percent of the fruit showed decay. When all cars were included 1.9 percent of the fruit was affected. Of this 1.9 percent, brown rot accounted for 1.3 percent, or about two-thirds, of the rot, and rhizopus rot for 0.6 percent, or about one-third. All other decays apparently were present in insignificant amounts, if at all. An examination of the dumping certificates for the Chicago market during 1941 to 1946, inclusive, by Ramsey, Smith, and Heiberg (*181*) showed that shipments of peaches were so badly decayed that they required dumping in only 2 out of the 6 seasons. In one of those years 2,500 pounds (about 50 bushels), and in the other 19,776 pounds (about one carload), were dumped because of excessive rhizopus rot and brown rot.

Figures compiled by the Association of American Railroads and reported by Smith (*200*) show that the average loss per carload of peaches from 1943 to 1948, inclusive, ranged from a low of $15.63 in 1944 to a high of $63.89 in 1948. These figures included losses other than decay (such as breakage), but it is assumed that decay was responsible for a large proportion of the losses. In a report (*231*) of precooling and loading trials with peaches, it is stated that one railroad paid claims of more than $50.00 for every $100.00 of peach revenue in 1949—and much of the loss was attributed to brown rot.

These losses are reported for peaches grown in the central and eastern peach regions. Peaches grown in the dry irrigated sections of the West are less subject to decay, and the predominant rot is likely to be rhizopus rather than brown rot.

Inspection of peaches on arrival at terminal market does not adequately represent the seriousness of decay, as most decay develops after arrival. Peaches are frequently precooled before shipment and are generally shipped under refrigeration. Under these cool conditions decay makes practically no progress. However, after arrival at the market the fruit is generally exposed to warm temperatures at which decay develops very rapidly. This has been pointed out by Haller (*81*), who showed that lots in which decay was only 1.5 and 2.1 percent on arrival had 12.6 and 10 percent decay after only 1 day at room temperature, and individual baskets had as high as 26 percent. This represents a fivefold to eightfold increase in only 1 day, which is not time enough for most of the fruit to become ripe or even to have reached the consumer.

Additional evidence of the seriousness of decay in peaches is to be found in other reports. The development of 22 to 75 percent decay in four out of six shipments of 48 hours' duration is reported by Fawcett and Burkholder (*65*). Burkholder and Sharvelle (*36*) held samples of Indiana peaches from different orchards at room temperature for 4 days (by which time most of the fruit probably became ripe). Losses from brown rot ranged from 28 to 66 percent in the 1946 season, and from 10 to 100 percent in more than 100 samples in the 1947 season. Cation (*41*), in Michigan, reported that only 45 percent of the peaches from his best spray treatment in 1947 were sound after 4 days at room temperature. Cravens and Cardinell (*46*) reported that a fifth of the replies to questionnaires sent to retailers and consumers indicated that at least 20 percent decay had been found, and about two-fifths of the replies indicated 2 to 20 percent decay.

A serious outbreak of anthracnose, or bitter rot, occurred on peaches grown in southern Georgia in the 1949 and 1950 seasons. It was sufficiently serious in 1949 to cause some lots of fruit to be rejected at the shipping point (*200*).

BROWN ROT

This review is primarily concerned with disorders as they occur on the market. However, in the case of brown rot, inoculation probably occurs largely in the orchard, and its control on the

market is so profoundly influenced by growing conditions and orchard control of the disease that consideration of these factors is of great importance.

Life History

The brown rot organism overwinters chiefly on mummified fruits that adhere to the branches or fall to the ground, and to a less extent in twig and limb cankers (*184*). Spores from these sources infect blossoms and twigs in the spring. During wet weather spores are formed on infected blossoms, cankers, and mummies. These spores are disseminated by wind and rain, and many of them may lodge on the fruit. Although Brooks and Cooley (*32*) stated that the brown rot organism is parasitic and can grow on living material such as unripe peaches, it very seldom attacks the fruit until it approaches maturity. The disease becomes most severe as the fruit ripens after harvest. When brown rot is prevalent in an orchard there may be decaying fruit, covered with the sporulating fungus, on the trees at picking time. In handling such fruit, spores are transferred to the pickers' hands and then to the surface of picking bags, field crates, and grading equipment. Thus, spores from one partially decayed peach might inoculate hundreds of sound fruits.

Wet, humid weather is favorable to the sporulation of the brown rot organism and to the germination of the spores. It has long been recognized that wet weather, particularly just previous to or during the harvest season, is favorable to brown rot development in the fruit (*30, 184, 185, 219, 229*).

Increased susceptibility of the fruit to brown rot has also been attributed to nitrogen fertilization. Petersen (*176*) reported that in an orchard with severe blossom infection there was at harvest very little brown rot on the fruit from trees grown under sod conditions (low-nitrogen growth status), but that severe brown rot was present where a cover crop had been disked in (resulting in high-nitrogen growth status late in season). In a survey, Petersen found that severe brown rot in peaches was generally associated with soil-building practices that resulted in a high-nitrogen condition. Havis (*97*) also indicated that heavy nitrogen fertilization favored brown rot in the fruit, but he attributed the result to reduced air movement and higher humidity around the fruit—caused by the heavier foliage of the nitrogen-fertilized trees. Angell (*12*) observed great variability in the incidence of brown rot in peaches from different trees growing within a short distance of each other. When sporulating cultures of the brown rot organism were suspended in a tree with relatively low brown rot incidence, the percentage of incidence remained relatively low. Angell concluded that the main factor contributing to the incidence of brown rot was neither weather nor a build-up of inoculum, but was one induced by conditions peculiar to the immediate environment of the tree—possibly soil differences.

Relation of Maturity and Ripeness to Infection

Although brown rot spores may be present on the fruit throughout the growing season, and conditions may be favorable for spore germination, the fruit very seldom becomes infected until it approaches picking maturity. Infections become more severe as the fruit becomes riper (*185*). Willison (*229*) divided peaches into two stages of maturity and reported that more brown rot developed on the more mature lot. Hamilton (*87*) inoculated peaches of four degrees of maturity and held them at two temperatures. In a moist chamber at 74° F., ripe and firm-ripe peaches became infected in 10 to 12 hours, light-yellow (firm) peaches required 24 hours, and green peaches required 36 hours. At 63° the corresponding times were 24 hours for ripe, 48 hours for firm ripe, 66 hours for firm, and 85 hours for green. There seems to be no information as to why it takes longer for the brown rot fungus to enter less mature peaches, why it fails to infect immature peaches, or what becomes of spores that lodge on immature peaches but fail to infect them under conditions favorable for spore germination.

Relation of Injury to Infection

Smith (*199*) made histological studies of infection of Elberta peaches by the brown rot organism. In practically all cases he found that the germ tube entered the peach at the base of the root hairs, between the root hair and adjacent buffer cells. This was true both with brushed and nonbrushed fruit, and it demonstrated that the organism could penetrate through the uninjured skin of the fruit—as it did even with brushed fruit. Infection of brushed fruit occurred sooner (4½ to 8 hours) than that of nonbrushed fruit (8 to 10 hours). The slower infection of nonbrushed fruit was attributed to the longer distance between the spores and the surface of the fruit when they were held out by the fruit hairs.

Although brown rot can infect peaches through the unbroken skin, it is not likely that all spores lodging on the surface of the fruit would enter, even though no protective fungicide were present. Germinating spores on immature fruit may fail to enter because of the resistance of such fruit to infection. Smith (*199*) has indicated that the germ tubes may grow in any direction, so that many probably grow away from rather than toward the hair sockets. In inoculation studies by Haller and others (*85*), it was necessary to inoculate each sound, brushed peach with at least a thousand spores of the brown rot fungus in order to obtain infection of 50 percent of the fruit. This indicated that less than 0.1 percent of the spores caused infections.

It is likely that spores lodging on the bare flesh, as in a cut or tear in the surface, would have conditions very favorable for germination and for penetration of the fruit. Much of the brown rot that occurs may enter through such wounds. Brooks and Cooley (*33*) dusted both sound and punctured peaches with *Monilinia* (brown rot) spores. Infection of the punctured peaches was 100 percent, but there was practically no infection of the sound

peaches. They concluded that infection could take place through the unbroken skin, but that under commercial conditions most infection was probably through wounds. Lloyd and Newell (*132*) shipped both sound and punctured (cut with thumbnail) peaches. They found no decay in the uninjured peaches. In the punctured lots there was 18 percent decay, with the decay starting at the punctures in all cases.

Roberts and Dunegan (*184*) stated that infection with brown rot may take place through the uninjured skin of peaches but that it is more likely to occur at punctures. Willison (*227*) found that bruising did not markedly contribute to increased decay unless the skin was broken. Merrill (*153*) found less brown rot decay in peaches packed in a cell-type carton than in bushel baskets. The reduction in decay was attributed to reduced bruising. Cravens and Mauch (*47*) observed that about 60 percent of rots occur at the stem end in injuries from picking. In this connection, Hitz, Simons, and Schell (*108*) found that in commercial picking 36 to 46 percent of the peaches were ruptured and the flesh exposed at the stem end. By 4 days after harvest brown rot had developed at the rupture in 14 to 80 percent of such peaches. The wide variation in percentage of decay depended largely on where the samples were selected. The lowest percentage (14) was found in samples taken at time of picking, and the highest percentage (80) in samples taken after brushing and grading. The investigations indicate that the handling and dumping of peaches into baskets or field crates by the pickers and the cleaning operation (brushing) are two important points of contamination. They found that in bulk packages (bushel baskets) an average of 25 percent of the infections occurred at stem ruptures, 16 percent at skin punctures, and 31 percent at points of contact with other rotting peaches. This would leave about 28 percent that presumably entered through the unbroken skin. In cell-type cartons the percentage of decay at contact points was only 7.5 percent as compared with 31 percent in baskets. About 40 percent of the decay was at stem ruptures, 20 percent at skin punctures, and 33 percent through the unbroken skin.

Varietal Susceptibility

None of the commercial varieties of peaches are immune to the brown rot organism, but some appear to be less susceptible to infection than others. No systematic studies have been made of the relative susceptibility of different varieties, as weather during the harvest period is generally more important than variety. Havis (*97*) listed Red Bird, Rochester, Fisher, and Oriole as susceptible, and Elberta, Red Haven, Dixigem, Triogem, Sunhigh, and Sullivan Elberta as relatively resistant. Blake and Edgerton (*22*) indicated that Fireglow is susceptible.

Control by Orchard Treatments

Since the primary source of brown rot inoculum is in the orchard, any treatment that reduces this source should reduce decay

after harvest. Although orchard control of brown rot is somewhat out of the field of this review, results of orchard treatments are discussed where they have a bearing on postharvest occurrence of this disease.

The literature previous to 1932 on the life history and control of brown rot of peaches has been reviewed by Roberts and Dunegan (*184*). They indicate that control of brown rot is dependent upon a number of factors, including: (1) Sanitation (removal and destruction of mummies, pruning out of cankers, removal of decayed fruit at harvest, and other measures), (2) control of insects, such as plum curculio and oriental fruit moth, that may inoculate fruit with brown rot, (3) blossom sprays to control the blossom-blight phase of the disease, (4) cover sprays, including preharvest sprays to protect the fruit from later inoculation, (5) postharvest treatments with dips, sprays, dusts, or fumigants to disinfect the fruit before shipment to market, and (6) refrigeration to retard the germination and development of the organism in transit. Willison [16] lists control measures for brown rot as: (1) Removal of rotted fruit from tree and ground, (2) complete spray program from preblossom sprays to prepick sprays, (3) avoidance of handling rotted fruit and keeping it out of the packing house, (4) prompt packing and shipping (refrigeration is no substitute for orchard-control measures), (5) precooling, and (6) wrapping (he obtained better control of postharvest decay by spraying if peaches were wrapped).

Certain cultural practices may contribute to some extent to infection by brown rot. Mitchell (*159*) reported that growers in Tennessee were able to reduce brown rot of peaches from 100 percent to 10 to 30 percent by heavy pruning and tree removal, to permit more effective spraying, and by sanitation (mummy removal and pruning out of cankers). Havis (*97*) pointed out that high humidity and lack of air movement are favorable to brown rot. Such conditions may be due to close planting, severe pruning, especially cutting back, and heavy nitrogen fertilization. He suggested (as a means of reducing brown rot) planting trees at least 25 feet apart, a thinning-out type of pruning, and light nitrogen applications. He also suggested thinning fruits so that they do not contact each other. He further stated that fruit affected with brown rot should not be handled with sound fruit in picking and packing.

Brooks (*30*) made 11 test shipments of Georgia peaches from sprayed and nonsprayed plots during four seasons (1921–24). Inspection on arrival at destination showed that spraying had reduced the average brown rot from 21.7 percent to 5.2 percent. The spray treatments were not given in detail but consisted of a full schedule. Rudolph (*186*) observed that control of the fruit-rot stage of brown rot depended chiefly on the control of the blossom-blight phase, the phase which is responsible for initial infection of the fruit.

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[16] See footnote 8, p. 15.

The control of brown rot on the fruit by orchard sprays primarily involves two factors: (1) The time and number of applications, and (2) the material or fungicide used.

In general, the results indicate that blossom sprays are extremely important. In experiments with two varieties extending over five seasons, Willison (*229*) found only slight benefit from prepick sprays (2 to 3 days before picking), but he obtained considerable benefit from two applications against the blossom-blight phase of the disease, followed by one cover spray 3 weeks before harvest. Dunegan and Goldsworthy (*64*) also emphasized the importance of controlling the blossom-blight phase in order to control brown rot on the fruit. When they used cover sprays or dusts of wettable sulfur throughout the season, but no blossom sprays, there was 33 percent blossom blight, and after harvest 46.6 percent of the fruit was affected with brown rot. When four blossom sprays of 2,3-dichloro-1,4 naphthoquinone (Phygon) were added to this schedule, blossom blight was reduced to only 2 percent and fruit rot after harvest to 11.8 percent.

Poulos (*178*) reported on spray applications to an abandoned peach orchard in which decay in peaches from unsprayed lots averaged 56 percent at harvest. A complete program of five blossom-blight sprays, plus three midsummer sprays, followed by five preharvest sprays reduced the decay to only 2 percent at harvest. When the three midsummer applications were omitted, the decay was 8 percent; and when both the midsummer and blossom-blight sprays were omitted the decay averaged 65 percent (an apparent increase with preharvest sprays only over the unsprayed). These data indicated that bloom applications were the most important, that summer applications were of some value, and that preharvest applications were of no benefit.

Dunegan (*63*) reported on a survey of the number of brown rot infection sources near harvesttime in four commercial orchards that had received different numbers of blossom sprays. He found a striking inverse relation between the number of blossom sprays and the number of infection sources. With no blossom sprays there were 50 infection sources (blighted blossoms, sporulating twig cankers, or infected fruit) to every 100 fruits, with one blossom spray the ratio was 10 to 100, with two blossom sprays it was 2 to 100, and with four blossom sprays it was only ½ to 100. The chance of fruit rot at harvesttime was considered to be proportional to the number of infection sources.

Copper fungicides cannot be used in orchard sprays for peaches because of injury to the leaves. Consequently, the fungicide recommended in standard spray schedules has been some form of sulfur, such as liquid lime sulfur, wettable sulfur, or sulfur dust. In recent years some of the newer organic fungicides have been tried, but some form of sulfur is still commonly used. Experimental results with sulfur follow:

Sulfur.—Some tests have been made to study the relative effectiveness of the different forms of sulfur, particularly as preharvest applications. Hurt (*116*) stated that sprays of wettable sulfur, or

dusts of pink dusting sulfur, used before harvest were effective in reducing brown rot on the fruit, although no data are presented and there is no indication that one form was more effective than another. Willison (*227*) applied preharvest sprays of different brands of wettable sulfur (Koloform, Kolofog, Kolopick, Bartlett's Prepick, and Qua-Sul) and sulfur dust to two varieties of peaches. All greatly reduced but did not completely control brown rot. Willison stated that the different brands or forms of sulfur were about equally effective, except that the sulfur dust was somewhat less effective than the sprays when rain occurred shortly after application.

Fawcett and Burkholder (*65*) reported good results with liquid lime sulfur, but did not have comparisons with other forms of sulfur. Weaver (*219*) reported on postharvest decay in peaches from plots that were given nine blossom and cover sprays of (*a*) lime sulfur, (*b*) wettable sulfur (6–100), and (*c*) sulfur dust (85–15). Best results were obtained with wettable sulfur (12 and 11 percent decay), followed by sulfur dust (21 percent decay), and with lime sulfur giving poorest control (23 and 38 percent decay).

Heuberger and Poulos (*102*) reported that liquid lime sulfur (1 quart to 100 gallons) plus Sulfuron (2 ounces to 100 gallons) as a preharvest spray showed appreciable control of brown rot, whereas liquid lime sulfur alone failed to control brown rot in the orchard or after harvest, and caused foliage injury. In a later report, Poulos and Heuberger (*179*) applied the test materials to two varieties in four preharvest applications. Sulfuron (4 ounces to 100 gallons) did not injure the foliage and reduced decay to 23 percent in the orchard and 45 percent after harvest, as compared with 38 and 72 percent, respectively, for the check. On the other hand, Poulos (*178*) applied five preharvest sprays of Sulfuron X (5 ounces to 100 gallons) to an abandoned peach orchard at 5-day intervals and obtained an apparent increase in decay at harvest to 65 percent, as compared with 56 percent on the unsprayed fruit.

Poulos and Heuberger (*179*) stated that a combination of liquid lime sulfur (1 quart to 100 gallons) plus Sulfuron (2 ounces to 100 gallons) appeared promising. They again reported that liquid lime sulfur (2 quarts to 100 gallons) caused injury. Burkholder and Sharvelle (*36*), on the other hand, used liquid lime sulfur at concentrations of 2 to 3 quarts to 100 gallons in two preharvest applications and obtained appreciable reduction in brown rot. They reported no injury to the fruit or leaves. They used a mist-type spray (from small-aperture disks in the spray gun), which they considered safer than a drenching type of spray. This treatment was much more effective than sulfur dust. Sharvelle and Burkholder (*191*) recommended that three preharvest sprays (four in wet seasons) be applied at about 10-day intervals, using wettable sulfur or liquid lime sulfur. Foster (*68*) found that seven applications of wettable sulfur in a complete spray program gave very good control of brown rot of the fruit after harvest.

Poulos (*178*) obtained very effective control of brown rot in an

abandoned orchard by use of a complete spray program consisting of five blossom sprays of flotation sulfur (12 ounces to 100 gallons), three midsummer sprays of Sulfuron X (6 ounces to 100 gallons), and five preharvest sprays of Sulfuron X (5 ounces to 100 gallons). This program reduced brown rot at harvest from 56 percent on unsprayed lots to only 2 percent on the sprayed. Petersen and Cation (*175*) reported that four preharvest applications of sulfur dust reduced brown rot at harvesttime to 3 percent, as compared with 7 percent when preharvest applications were not used. In another orchard with much heavier infection they obtained somewhat less decay (67 percent) by using wettable sulfur than by using liquid lime sulfur (84 percent decay).

Results of tests indicate that, in general, effective control of brown rot can be obtained with different forms of sulfur used throughout the spray program, and that one form is no more effective than another.

Some of the newer organic fungicides that have been tested for orchard sprays are:

Cycloheximide (Acti-dione).—This is an antibiotic that has fungicidal properties. It was tried in preharvest sprays by Petersen and Cation (*175*) at 2, 5, and 10 p. p. m. in four applications. In an orchard with low infection it held brown rot infection to 0 and 2 percent, as compared with 7 percent on check fruit. In another orchard, with heavy infection, decay was 89 percent when liquid lime sulfur was used, 84 percent with Acti-dione (20 p. p. m.), and 67 percent with wettable sulfur. Acti-dione at 20 p. p. m. did not injure the leaves, but it caused severe cracking of the fruit. There was less cracking at lower concentrations, but mottling of the fruit occurred at all concentrations. Because of the injury to the fruit this material was unsatisfactory, and with heavy infection did not give satisfactory control.

Dithiocarbamate.—This material was tried in preharvest sprays by Poulos and Heuberger (*179*) and was reported to be ineffective.

Dithiocarbamate, ferric dimethyl (Fermate (ferbam)).—This is another material tried by Heuberger and Poulos (*102*) and found to be ineffective.

Dithiocarbamate, zinc dimethyl (Zerlate (ziram)).—This material has been tested at several stations against brown rot, generally in preharvest applications. Powell (*180*) reported that Zerlate used as a preharvest spray in Illinois was more successful than sulfur in preventing postharvest brown rot of peaches. Fawcett and Burkholder (*65*), in Indiana, also reported that Zerlate sprays before harvest were effective in reducing decay. Burkholder and Sharvelle (*36*) reported that two preharvest sprays of Zerlate were somewhat less effective in controlling brown rot than liquid lime sulfur, but appreciably better than sulfur dust. Cation (*41*), in Michigan, used Zerlate in a complete spray program. He indicated that Zerlate was not superior to paste or wettable sulfurs. Heuberger and Poulos (*102*), in Delaware, used Zerlate combined with lime, and combined with Parzate and lime, in preharvest sprays. They list these combinations among materials

that failed to show appreciable control of fruit rot. In a later report, Poulos and Heuberger (*179*) again list Zerlate among materials that were not effective against brown rot. Foster (*68*), in South Carolina, used Zerlate only in the cover sprays of a complete spray program. He reported that Zerlate gave effective brown rot control in the fruit after harvest, but that it was possibly less effective than wettable sulfur. Hamilton (*87*) used Zerlate (1 pound to 100 gallons) in preharvest treatments and reported it more effective than wettable sulfur (5 pounds to 100 gallons). These results indicate that Zerlate is effective in reducing brown rot and that it does not injure the fruit.

Dithiocarbamate, zinc ethylene bis- (Dithane Z-78, Parzate (zineb)).—This compound was reported by Poulos and Heuberger (*179*) to be ineffective when used in preharvest sprays. Cation (*41*) listed Parzate among materials that were not superior to wettable sulfur in controlling peach decay. Heuberger and Poulos (*102*) used Parzate with lime, and combined with Zerlate or Fermate, in preharvest sprays. They reported that these combinations did not show appreciable control of rot on the fruit. In a later report, Poulos and Heuberger (*179*) list Parzate as ineffective in preharvest sprays.

1,4-naphthoquinone, 2-3-dichloro- (Phygon).—This material gave outstanding control of blossom blight when used in four blossom sprays, according to Dunegan and Goldsworthy (*64*). Rot of the fruit after harvest was 11.8 percent when this treatment was followed by cover sprays of wettable sulfur throughout the balance of the season, as compared with 46.6 percent when only the cover sprays of sulfur were used. Cation (*41*) reported on tests with various fungicides used as blossom sprays and summer sprays. He indicated that Phygon was no more effective than paste or wettable sulfurs. Heuberger and Poulos (*102*) used Phygon with a spreader in preharvest sprays, but listed it among the materials that were ineffective in controlling brown rot in the fruit. Foster (*68*) reported that Phygon was effective in controlling brown rot when used in a complete spray program, but that it caused injury. The results cited do not indicate that Phygon is a promising fungicide for the control of brown rot of peaches, except possibly in blossom sprays. Even here there is no evidence that it is superior to other materials that might be used.

N-trichloromethyl thio-tetrahydrophthalimide (SR 406 or Orthocide 406).—This compound was tested by Hamilton (*87*) in preharvest sprays. The sprays were followed by artificial rain, and the fruit was inoculated with spores of the brown rot organism after harvest. Hamilton reported that SR 406 was more effective than sulfur but not as good as Zerlate or Bioquin 1.

Copper 8-hydroxquinolinolate (Bioquin 1).—This material has been tried in preharvest sprays by Heuberger and Poulos (*102*), Poulos and Heuberger (*179*), Morgan and Powell (*161*), and Hamilton (*87*). Heuberger and Poulos (*102*) used it with lime and reported it was the most effective of the materials used

in controlling brown rot in the orchard and after harvest, but that it caused injury to the foliage and discolored the fruit. In the tests covered by a later report (*179*), Bioquin (½ ounce to 100 gallons) was used with a wetting agent in four preharvest applications to two varieties. It was again reported as the most effective material for brown rot control, but also as again causing injury. Morgan and Powell (*161*) used different wetting agents, and they inoculated the fruit with spores of the brown rot organism. With peaches receiving no preharvest sprays, 38 percent developed brown rot after harvest. This was reduced to 28 percent by use of copper 8-hydroxquinolinolate alone, and to 12 percent with the addition of the most effective wetting agent (Triton B 1956). The investigators do not indicate whether the material caused any injury or discoloration of the fruit. Hamilton (*87*) also reported that Bioquin was very effective in controlling brown rot on inoculated peaches. He did not indicate any injury or discoloration.

These results are in agreement that copper 8-hydroxquinolinolate is a very effective fungicide against the brown rot organism on peaches, but that it is likely to cause injury or discoloration of the fruit.

Quinolinolate, zinc 8.—This compound was tested by Cation (*41*) in a complete spray program, but he indicated that the material was not superior to paste or wettable sulfurs in controlling brown rot on the fruit.

Sodium hypochlorite (Clorox).—Clorox was tried in preharvest sprays by some growers. Favorable results in control of brown rot were reported, according to Mason (*148*). He presented no data, and there is no indication of check blocks for comparison. Poulos (*177*) also reported on the use of Clorox (100 p. p. m. of Cl) in 2, 3, or 5 preharvest sprays on three varieties. Contrary to the results reported by Mason, no reduction in brown rot was obtained by Poulos, either with Clorox alone or when combined with Sulfuron. Concentrations of 250 to 2,000 p. p. m. of chlorine injured (bleached) the foliage.

In addition to the above materials, Goldsworthy and Gertler (*73*) tested in the laboratory more than 500 synthetic organic compounds for their fungicidal properties to the brown rot organism and for their phytotoxic effect on peach leaves. They list 10 promising compounds that possessed satisfactory fungicidal action, were stable when mixed with insecticides, lime, and adjuvants, and were noninjurious to peach foliage, as follows:

1. Acetanilide, *p*-chloro-alpha-isonitroso-
2. Aniline, *p,p′*-thiodi- (4,4′-diamino diphenyl sulfide)
3. Benzamide
4. Benzimidazole
5. Benzoic acid, *p*-chloro-
6. Benzoic acid, 3,4-dichloro-
7. Glycinonitrile, N-(*o*-methoxyphenyl)-
8. Phenol, 2,2′-methylenebis[4-chloro-
9. Phenol, 2,2′-(2,2,2-trichloroethylidene)bis-[4-chloro-
10. Phenol, 4,4′-isopropylidenedi-

Some of these materials are not available commercially, and none of them have been tried in field experiments for the control of brown rot, so that their practical value has not been determined.

Some have been tried for postharvest treatment of the fruit and will be discussed in that connection.

Packing-House Control

Control of brown rot after the fruit is harvested has consisted primarily of (1) treatments in the packing house (occasionally in transit) designed to reduce the load of viable spores of decay-producing organisms on the fruit, and (2) precooling and refrigeration in transit to retard the germination of the spores and growth of the organisms. This section deals particularly with disinfectant treatments in the packing house. The temperature relations of the decay-producing organisms are discussed in a subsequent section (p. 85).

Disinfectant Treatments

A satisfactory disinfectant material must be (1) toxic to the decay-producing organism, (2) nontoxic to the fruit in concentrations at which it is toxic to the organism, (3) nontoxic to humans in the amounts that might remain as residues on the fruit, (4) inexpensive, both in cost and in application, and (5) odorless and tasteless, so that it does not impart off-flavors to the fruit, and (6) it must leave little or no visible residue on the fruit. Many materials have been tried in recent years in an attempt to find something more effective than sulfur dust, which is now commonly used. The results obtained with the various materials follow:

Benzamide.—This is one of the materials listed as promising in laboratory tests by Goldsworthy and Gertler (*73*). Haller and others (*85*) tested this material as a 5-percent dust and reported it ineffective on peaches inoculated with spores of the brown rot organism.

Benzimidazole.—This is another of the materials listed by Goldsworthy and Gertler (*73*) as promising but reported to be ineffective by Haller and others (*85*) when used as a 5-percent dust on peaches.

Benzoic acid, p-chloro-, and *benzoic acid, 3,4 dichloro-.*—These two materials were also listed by Goldsworthy and Gertler (*73*) as promising but were reported by Haller and others (*85*) to be ineffective when each was used as a 5-percent dust on peaches.

Bis (2 hydroxy-5 chlorophenyl) sulfide (CR 305).—Peaches dipped in 0.25- to 1.0-percent solutions of this material showed promising reduction in brown rot in one test, slight reduction in a second, and none in a third, as reported by Haller (*81*). The results are therefore inconclusive, and further tests with this material might be justified.

Calcium chloride.—Heuberger, Poulos, and Hood (*103*) used calcium chloride as a dip for peaches at concentrations of 0.25 to

1.0 percent. They report that these solutions gave no control of decay.

Carbon dioxide.—Treatments with high concentrations of CO_2 in the atmosphere have been used to retard ripening and decay in other fruits, such as cherries. The effect of CO_2 on ripening and flavor in peaches has been discussed on p. 50. Brooks and others (*34*) studied the effect of CO_2 on peaches inoculated with spores of *Rhizopus* and *Monilinia* (brown rot) in experimental chambers and in commercial shipments. CO_2 was found to retard greatly the development of brown rot. At 77° F., within a range of 10 to 40 percent, the carbon dioxide had an effect upon the brown rot organism of reducing the temperature approximately as many degrees as the percentage of gas used. At lower temperatures the effect of CO_2 on the fungus was equally great, if not greater, but the equivalent temperature reduction was necessarily less.

Brooks, Schomer, and Bratley (*35*) reported on shipping tests with peaches grown in Georgia in which solid CO_2 (dry ice) was used as a source of the gas. They found that 100 pounds of solid CO_2 in truck shipments and 500 pounds in refrigerator-car rail shipments did not produce concentrations of CO_2 high enough to retard decay appreciably. In later tests, when 450 pounds and 700 to 800 pounds were used in trucks and refrigerator cars, respectively, there was an appreciable reduction in decay. Solid CO_2 was slightly more effective when placed over the top of the load than when placed over the ice in the bunkers. The concentration of CO_2 obtained in refrigerator cars varied considerably with the gastightness of the cars. On the other hand, Tindale, Huelin, and Trout (*207*), who held peaches at 32° F. in air and in different concentrations of CO_2, reported no reduction in brown rot from use of CO_2 when the peaches were subsequently ripened at 65°.

Although CO_2 has shown some promise in reducing brown rot, it can adversely affect the flavor of the fruit (see p. 50), depending on the concentration, temperature, and time of exposure. As it is difficult to regulate the concentration of CO_2 in refrigerator cars, there would be danger of the concentration getting so high that it would affect the flavor of the fruit or so low that it would not retard brown rot development.

Chlorine.—This material has been rather extensively tested against brown rot of peaches (see p. 74 for preharvest applications). Chlorine has also had commercial trial as a disinfectant in water used for precooling (p. 56). In this treatment, designated as "stericooling" or "hydrocooling," ice water, to which a chlorine-type germicide, "Hypo-chlor," has been added, is pumped over the fruit long enough to cool it. The fruit is treated after it is packed in shipping containers.

Cardinell and Mitchell (*39*) reported that peaches that showed 44 and 61 percent decay after being dusted with sulfur plus 10-percent Zerlate showed only 23 and 39 percent decay, respectively, after being stericooled with 130 p. p. m. of chlorine in the water. Barr and Slade (*18*) reported on one test shipment in which decay

was 0.5 percent in the stericooled lots, as compared with 21 percent in the check fruit. Cardinell and Barr (*38*) reported that the average decay of fruit after different periods at room temperature was 41 percent when dusted with sulfur, 43 percent when precooled with ice water, 37 percent when treated with 100 p. p. m. of chlorine (from Hypo-chlor) at room temperature, and 33 percent when treated with chlorine in ice water. They concluded that the Hypo-chlor treatments greatly reduced decay. However, the differences are of questionable statistical significance.

Cravens and Cardinell (*46*) indicated that retailers and consumers reported as much decay on peaches that had been stericooled as on those that had been dusted with sulfur. Link and Pancoast (*130*) stericooled peaches before storing them for canning. They reported a 10- to 15-percent increase in yield of canned product over conventionally cooled fruit, presumably due to reduced decay. Schomer and Lieberman (*189*) used higher concentrations of chlorine (1,000 to 10,000 p. p. m.) for 10 to 15 minutes at room temperature and at 140° F. Appreciable reduction in decay was obtained with 1,000 p. p. m. of chlorine. Reduction was even greater at 2,000 p. p. m. There was no appreciable injury at 2,000 p. p. m. at tap-water temperature (68°), but there was serious injury at 140°, even with chlorine concentrations as low as 1,000 p. p. m. Chlorine at concentrations of 2,500 p. p. m. or more caused injury even at tap-water temperature. Haller (*81*) also reported decay reduction with chlorine dips at concentrations of 1,000 and 2,000 p. p. m., but chlorine was no more effective than sulfur dust. Although not stated in the report, higher concentrations caused injury. Very slight injury, consisting of a light-brown streaking of the skin, was sometimes observed, even at 2,000 p. p. m. concentration.

Heuberger, Poulos, and Hood (*103*) reported on the use of chlorine dips, using several sources of chlorine as liquid Chlorax (sodium chlorate at 500 to 4,000 p. p. m. Cl), powdered Chlorax (sodium chlorate at 250 to 4,000 p. p. m. Cl), Clorox (sodium hypochlorite at 500 to 4,000 p. p. m. Cl), and a slurry of nitrogen trichloride (100 to 2,000 p. p. m. Cl). When tested on three varieties, the chlorine compounds did not significantly reduce decay at low concentrations, and at high concentrations they caused injury. Hamilton (*87*) also used Clorox as a postharvest dip (concentrations not given), and he stated that it was wholly unsatisfactory.

In general, the results indicate that chlorine reduces decay at concentrations of 1,000 to 2,000 p. p. m., but is not outstanding in this respect. There is also danger of injury if the concentration becomes too high. Since decay control is only fair at chlorine concentrations of 1,000 to 2,000 p. p. m., it seems doubtful whether concentrations of about 100 p. p. m., as used in stericooling, would be of any benefit.

Chromates, copper-zinc complex (Crag 658), and *chromates, copper-zinc-calcium-cadmium complex* (Crag 531).—These materials were tested by Haller and others (*85*) as 5-percent dusts

and as 2-percent sprays. They reported that these materials were ineffective against brown rot in postharvest treatments.

Copper 8-hydroxquinolinolate (Copper 8 or Bioquin 1).—This material was tested by Haller and others (*85*) as a 5-percent dust and as 1- and 2-percent sprays. They reported that this material was very effective in reducing brown rot, but that it left an unsightly residue.

Copper oxychlorides (Copper A).—This material was also tried by Haller and others (*85*) as a 5-percent dust. They reported that it gave fair control of brown rot (about 50-percent reduction with artificial inoculation). Additional tests with this material might be desirable.

Copper sulfate.—Heuberger, Poulos, and Hood (*103*) used copper sulfate (0.5 to 125 p. p. m. of Cu) in dip treatments on three varieties. They reported that it gave no control of brown rot.

Cycloheximide (Acti-dione).—The antibiotic Acti-dione has also been used in postharvest dips (as well as in preharvest sprays) for brown rot control. Vaughn and Hamner (*217*) found that growth of the brown rot organism on culture plates was reduced 93 percent by Acti-dione at 20 p. p. m. Similar results have been reported by Whiffen (*223*) with concentrations of 5 to 20 p. p. m. Vaughn and Hamner (*217*) dipped peaches in 20, 50, and 100 p. p. m. of Acti-dione for 5 and 10 minutes and reported that brown rot was reduced from 58 to 77 percent on untreated, to 10 to 26 percent on the treated lots. No mention is made of injury to the fruit at any of these concentrations. Heuberger, Poulos, and Hood (*103*) dipped peaches in 5 to 20 p. p. m. of Acti-dione. They reported it was very injurious to the fruit. They did not indicate its effectiveness in controlling decay.

Haller, Smith, and Womeldorph [17] also found that at very low concentration Acti-dione was too injurious to peaches to be of value. Petersen and Cation (*175*) used Acti-dione in postharvest dips at concentrations of 20, 10, 5, and 2 p. p. m. With peaches that were very subject to decay (94 percent on checks), the Acti-dione was ineffective in reducing decay (95 to 84 percent decay on treated lots). They reported no injury to the Rochester variety of peaches at these concentrations of Acti-dione. They found severe injury to Elberta and Halehaven varieties when Acti-dione was used as preharvest sprays.

Hamilton (*87*) indicated that he used antibiotics as postharvest dips or dusts and that they exhibited no toxicity to the brown rot fungus. He did not indicate what antibiotics were used or at what concentrations. In general, the results with Acti-dione rather conclusively show that it has no value as a peach fungicide, as it is too toxic to the fruit and does not consistently reduce brown rot.

Diphenyl.—Diphenyl vapor from impregnated wraps and box liners has been used to control decay of citrus. Heiberg and Ramsey (*100*) tested diphenyl against a number of pathogenic organ-

[17] Unpublished data.

isms on plate cultures. Under these conditions diphenyl inhibited the growth of the brown rot organism. Liners and pads impregnated with diphenyl were used in a few commercial shipments from southern Georgia in the 1947 and 1948 seasons, and good control of decay was reported by the shippers. However, reports of off-flavors began coming in from the markets, and use of the liners was discontinued. Haller and others (*85*) tried a basket liner impregnated with a phenol compound in which the odor was reduced. In a holding test the liner gave excellent control of brown rot but imparted off-flavors to the fruit.

Disodium ethylene bisdithiocarbamate (Dithane (D-14).—This material was listed as ineffective at noninjurious concentrations by Heuberger, Munger, and Poulos (*101*), when used in postharvest dips.

Ethane, trichlor.—Trichlor ethane is a liquid of low boiling point that vaporizes rapidly at room temperatures. It was tested as a fumigant by Haller and others (*85*). Used at a concentration of 1 ml. per cubic foot (1 volume liquid to 28,000 volumes air) for 5 hours, it was not injurious to the fruit, but it failed to control brown rot.

Ethane, tetrachlor.—This is another low-boiling-point liquid that was tested by Haller and others (*85*) as a fumigant. When used at a concentration of 1 ml. per cubic foot (1 to 28,000) for 19 hours, it caused very severe injury to the fruit.

Ethane, pentachlor.—This is another low-boiling-point liquid that was tested by Haller and others (*85*) as a fumigant. At a concentration of 1 ml. per cubic foot (1 to 28,000) for 6 hours, it failed to control brown rot.

Ethylene dichloride.—This is also a low-boiling-point liquid tested by Haller and others (*85*). It was also reported to be ineffective against brown rot at a concentration of 1 ml. per cubic foot (1 to 28,000), with exposures of 6 to 20 hours.

Gas (Safe-delivery, unknown composition).—A fumigation treatment applied to the fruit after it is loaded into the cars has been available commercially in some sections in recent seasons. In this treatment (applied by the Skinner Machinery Co., Inc.) a material is poured under the floor racks, where it gradually vaporizes at car temperatures, and a second material is vaporized on a hot plate on top of the load. Haller and others (*84*) made two test shipments in which this treatment was used. In neither test did the gassing treatment significantly reduce brown rot in test lots of peaches.

Glycol, propylene.—Propylene glycol is a liquid of high boiling point. Haller and others (*85*) tested this material as a fumigant. When dispersed as an aerosol (0.5 gm. per cubic foot) it failed to control brown rot. When vaporized by heating (at a rate of 1 ml. per cubic foot) it gave some indication of reducing brown rot, but the results were not consistent. Jorgensen and Ornelas (*121*) reported that peaches were injured when treated with propylene glycol in equal parts of water.

Glycol, triethylene.—This is another high-boiling-point liquid tested by Haller and others (*85*) as a fumigant and reported to be generally ineffective.

Glyoxalidines (Crag 341 C).—Hamilton (*87*) listed Crag 341 C among materials that were tested for brown rot control and found inadequate. Haller and others (*85*) tried this material as a 2-percent spray. They reported slight injury to the fruit at this concentration.

3-(1-hydroxyethylidene)-6-methyl-2H-pyran-2,4 (3H)-dione, sodium salt (dehydroacetic acid, sodium salt).—Haller and others (*85*) reported that this material, used as a 2.5-percent dust, failed to give satisfactory control of brown rot. When used as a 1-percent spray there was no injury. No decay counts were made.

4,4′-isopropylidenedi-phenol (Bisphenol A).—This is one of the materials listed by Goldsworthy and Gertler (*73*) as promising in laboratory tests. Haller and others (*85*) tried it on peaches as a 5-percent dust. They reported only fair (50 to 60 percent) reduction of brown rot on inoculated fruit.

Lauryl isoquinolinium bromide (Isothan Q 15).—Heuberger, Munger, and Poulos (*101*) reported a reduction in decay with Isothan Q 15 used at a concentration of 2 quarts per 100 gallons. However, Hamilton (*87*) listed Isothan Q 15 among materials that were inadequate.

Manganese bis (probably manganese ethylene bis dithiocarbamate).—This material was listed by Hamilton (*87*) as inadequate in the control of brown rot.

Methyl bromide.—Methyl bromide has been used as a fumigant for insect control, and it has shown some fungicidal activity. Latta (*128*) treated Elberta peaches with 3 pounds of methyl bromide per 1,000 cubic feet for 90 minutes in a 15-inch vacuum. There was no apparent adverse effect to taste or quality. Latta made no observation relative to brown rot control under these conditions. Claypool and Hewitt (*44*) also fumigated with methyl bromide. They reported that it caused off-flavors in concentrations too weak to cause injury to the fruit, and that it caused injury at concentrations and exposure times too low to control decay. Kenworthy (*125*) treated Golden Jubilee peaches in an iced refrigerator car (53° F.) with 8 pounds of methyl bromide. He reported no injury to the peaches, but he did not indicate that they were tasted for off-flavors.

2,2′-methylenebis(4-chlorophenol) (G-4).—This is one of the materials listed by Goldsworthy and Gertler (*73*) as promising in laboratory tests against the brown rot organism. It was tested by Haller and others (*85*) as a 1-percent dust and as a 1-percent spray on peaches inoculated with spores of the brown rot organism. They obtained only moderate reductions in brown rot with this material.

1,4-naphthoquinone, 2,3-dichloro- (Phygon).—Hamilton (*87*) listed Phygon among the materials he tried and found to be inadequate in controlling brown rot. Haller and others (*85*) tested Phygon and found that as a 2-percent spray it caused severe

injury. Very good control of brown rot on artificially inoculated fruit was obtained with this material as a 5-percent dust, but this treatment caused moderate injury to the fruit.

Nitrophenol carbonate.—Haller and others (*85*) reported on the use of this material. As a 2-percent spray it caused slight to severe injury. As a 5-percent dust fairly good control of brown rot was obtained, and no injury was observed.

N-trichloromethyl thio-tetrahydrophthalimide (SR 406 or Orthocide 406).—Hamilton (*87*) listed SR 406 among materials that he tried but which gave inadequate control of brown rot. Haller and others (*85*) applied Orthocide 406 as a 5-percent dust and as a 1-percent spray to harvested peaches that were inoculated with spores of the brown rot organism. It was one of the more promising materials tested by them. It gave good to very good control of brown rot, either as a dust or as a spray, although in one test as a spray it caused slight to moderate injury to the fruit.

Orthophenylphenol (Dowicide 1).—Haller and others (*85*) tested Dowicide 1 as a 1-percent dust. It was reported to be a poor control of brown rot.

Orthophenylphenol, sodium salt (Dowicide A).—Haller and others (*85*) reported that Dowicide A gave poor control of brown rot as a 1-percent dust. They reported good control of brown rot but severe injury to the fruit when the material was used as a 1-percent spray.

Quarternary ammonium compounds (Hyamine 1622 and Hyamine 3258).—Hyamine 1622 was listed by Heuberger, Munger, and Poulos (*101*) as ineffective, and Hamilton (*87*) gave a similar rating to Hyamine 3258.

8 quinolinol sulfamate.—This material was tested by Haller and others (*85*) as a 5-percent dust and as a 1-percent spray. The dust gave good control of brown rot on inoculated peaches, but when applied as a spray the 8 quinolinol sulfamate caused slight to moderate injury.

Sulfur, hydrogen (H_2S).—Fumigation with 1 and 2 percent of hydrogen sulfide gas was tried by Haller and others (*85*). Control of brown rot was poor. Slight injury resulted with 1 percent of H_2S, and severe injury with 2 percent.

Sulfur dioxide (SO_2).—Schomer and Lieberman (*189*) used potassium metabisulfite ($K_2S_2O_5$) as a source of SO_2 vapor for prepackaged peaches. The $K_2S_2O_5$ alone was not effective as an antiseptic, and when combined with Clorox reduced the latter's effectiveness. The treatments also caused injury to the peaches. SO_2 is very injurious to most fruits (except grapes), and it is probable that it would be injurious to peaches in concentrations high enough to be toxic to decay organisms.

Sulfur dust.—Dusting with sulfur just as the fruit enters the brushes for defuzzing is practiced to a considerable extent commercially. Smith (*197*) dusted both brushed and nonbrushed peaches with sulfur. The dusting reduced brown rot after transit on both brushed and nonbrushed fruit. However,

decay was not severe in any of the lots. In a later experiment (*198*), Smith inoculated the peaches with brown rot after dusting and held them at constant temperatures of 40° to 85° F. for 12 days. The sulfur was effective in reducing rot at 40°, 45°, and 55°, but not at 65° or above. Sulfur is slowly volatile, and it is presumed that its fungicidal action is due to the vapor. Theoretically, therefore, it should be more effective at the higher temperatures, where it would be more volatile. Smith's results indicate that the action may be due to other than the volatile factor, since the sulfur was more effective at low than at high temperatures.

More recently Haller (*81*) has presented results indicating that sulfur dust reduced decay to about 60 percent of the amount on nondusted peaches. By applying the dust before the fruit enters the brushes, it is possible to get a more uniform coverage and less noticeable residue on the fruit. However, much of the dust would probably be removed with the fuzz. The results reported by Haller (*81*) did not indicate any more effective control of decay when a heavier but less uniform coverage was obtained by applying the dust after the fruit was brushed. In a later report. Haller and others (*85*) indicated good to very good control of brown rot with sulfur dust.

Sulfur, liquid lime.—Heuberger and Poulos (*102*) reported that liquid lime sulfur reduced brown rot on the fruit when used as a postharvest dip. In later abstract reports, Heuberger, Munger, and Poulos (*101*) and Heuberger, Poulos, and Hood (*103*) indicated that liquid lime sulfur was effective at concentrations of 1, 2, and 4 quarts per 100 gallons. Hamilton (*87*) also tried lime sulfur, but indicated that it was not effective in reducing brown rot following artificial inoculations. Haller (*81*) reported on the use of a liquid lime sulfur (2 quarts to 100 gallons) dip. The results indicated only a moderate reduction in total decay, no more than was obtained with sulfur dust. In a later report, Haller and others (*85*) indicated more effective control of brown rot in tests in which lime sulfur (2 quarts to 100 gallons) was used as a spray on inoculated peaches. In these tests liquid lime sulfur, wettable sulfur, and sulfur dust was about equally effective.

Sulfur, wettable.—Haller (*81*) reported on the use of a 0.5-percent suspension of wettable sulfur. He indicated about a 50-percent reduction in decay in one test, but failed to get any control in a second test. In a later report, Haller and others (*85*) reported very good control of brown rot on artificially inoculated fruit when wettable sulfur was used as a 1-percent spray.

Sulfur-nitrogen organic complex (experimental fungicides 974 and 5379).—Experimental fungicide 974 was tested by Haller and others (*85*) as a 5-percent dust. They reported that it gave poor control of brown rot. They also tested experimental fungicide 5379. As a 5-percent dust it also was ineffective, but as 1-percent spray it reduced brown rot from artificial inoculation about 50 percent, and as a 2-percent spray it reduced brown rot about 90 percent

2,2′ thio bis (4 chlorophenol) (Compound 30).—Haller and others (*85*) reported that this material caused severe injury when used as a 1-percent spray. When they used it as a 2.5-percent dust, it caused no injury but gave relatively little brown rot reduction.

2,4,5-trichlorophenyl acetate (Seedox).—Seedox was found to be extremely toxic to the brown rot organism on culture plates.[18] However, when tested on peaches (*85*) as a 0.5-percent dust and as a 1-percent spray it was relatively ineffective.

Ultraviolet light.—Ultraviolet light is known to have bactericidal and fungicidal properties, and it has been tried on peaches. As a result of tests in Georgia (*70*), it was stated that peaches treated with ultraviolet rays did not keep any better than the controls. Dewey and Pentzer (*56, 57*) exposed five lots of Elberta peaches to the maximum practical exposure of ultraviolet light (35 seconds at 6 inches), but they failed to get control of decay due to natural inoculation in four of the five lots. Decay was caused primarily by rhizopus rot and brown rot.

Wraps, plain.—Tissue wraps for peaches are used extensively in the West but not in the Central and Eastern States. Wraps might be expected to offer some physical resistance to the spread of disease. Tindale, Huelin, and Trout (*207*) held peaches at 32° F., wrapped in plain tissue and in waxed paper. Decay was as high in the wrapped lots as in the nonwrapped check lots when the peaches were ripened at 65°. On the other hand, Willison[19] lists wrapping in plain tissue as one of the control measures for brown rot. He states that he obtained the best control following orchard spraying when the fruit was wrapped and place-packed.

Wraps, iodized.—Huelin, Tindale, and Trout (*115*) tried iodized wraps in storage experiments with peaches. The wraps were of no value: they were not effective in controlling brown rot, caused skin blemishes, and rendered the fruit inedible by imparting off-flavors.

Wraps, plastic.—Wraps of different types of Cellophane, Pliofilm, and other materials have been used in prepackaging fruits and vegetables. Stahl and Vaughan (*205*) reported large and consistent reductions in decay of four varieties of peaches at four temperatures by wrapping the fruit in Pliofilm. Jorgensen and Ornelas (*121*) used Pliofilm as well as Cellophanes of different permeabilities to moisture. They did not give the amount of decay under the various treatments, but this was included in a general score based on appearance, taste, and other factors. Peaches wrapped in films that were highly moisture retentive, such as Pliofilm and MSAT Cellophane, declined most rapidly, apparently because of greater decay that was favored under these conditions of high humidity.

In a report of results obtained at the Dominion Laboratory of Plant Protection (*2*), in tests in which transparent plastic films

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[18] SMITH, W. L. Bureau of Plant Industry, Soils, and Agricultural Engineering. Unpublished data.

[19] See footnote 8, p. 15.

were used to cover baskets, it is indicated that heavy condensation of moisture occurred even though the films were perforated. Although such conditions would be expected to increase decay, it is stated that little if any more decay occurred in these packages when held at room temperature than in packages without the plastic covers, and that under refrigeration decay was often reduced by the cover.

In prepackaging tests in which peaches were overwrapped with different films, Hruschka and Kaufman (*112*) obtained results that indicated decay (mostly brown rot) was less in fruit wrapped in nonperforated films than in nonwrapped fruit. Where the decay was less, the carbon dioxide content in the package was high and the flavor abnormal. In a later test (*113*), decay averaged higher when nonperforated cellulose acetate was used (in which carbon dioxide accumulation would not be high) than when perforated MSAT Cellophane was used, and it was slightly higher in peaches wrapped in perforated MSAT Cellophane than in peaches left unwrapped. Schomer and Lieberman (*189*) also presented data showing less decay but higher carbon dioxide and off-flavors when peaches were wrapped in MSAT Cellophane than when wrapped in cellulose acetate.

Zinc dimethyl dithiocarbamate (Zerlate, or ziram).—Hamilton (*87*) listed Zerlate among the materials he tried and found inadequate for the control of brown rot.

Summary of Packing-House Treatments

Many packing houses are equipped with dusters to apply sulfur dust to the peaches, usually just ahead of the defuzzing brushes. Sulfur dust applied in an adequate amount to cover the fruit seems to meet the requirements of a satisfactory disinfectant treatment as outlined at the beginning of that section (p. 75). The material is economical, can be conveniently applied, is noninjurious to the fruit, and is relatively nontoxic to humans. Although better control of brown rot would be desirable, no other material has been shown to give consistently better results. The sulfur dust is usually applied ahead of the defuzzing brushes. In this way the dust is spread evenly over the surface of the fruit and there is no visible residue. However, the brushes undoubtedly remove a large proportion of the dust along with the fuzz. Somewhat more effective control might be expected if the dust were applied near the end of the brushing operation so that less would be removed.

Disinfectant dips or sprays that wet the fruit would probably be less practical than dusting, as most peach packing houses are not equipped for such treatments. Also there might be some objection by the sorters and packers to handling wet fruit. Unless wet treatments are shown to be definitely more effective than dust treatments, it is unlikely that they will be adopted.

Fumigation treatments can be conveniently applied to peaches after they are loaded into the cars. There would be certain advantages to this type of treatment if a suitable material could

be found that is effective against the decay organism and that is noninjurious to the fruit and also economical to use.

Temperature Relationship

Brooks and Cooley (*32*) studied the relation of temperature to the development of brown rot in inoculated peaches. They found that a temperature of 50° F. held the brown rot organism in check for 1 to 2 days. The time required for visible development was 3 days at 45.5°, 4 days at 41°, and 6 days at 36.5°. A delay of 1 day at 77° after inoculation greatly reduced the subsequent effectiveness of low temperature in retarding brown rot. However, decay developed very rapidly at high temperatures after removal of peaches from the low temperatures. They stated, "The results show the great value of low temperatures in controlling peach rots and the extreme importance of securing these temperatures promptly." They also observed that the organism grew on ripe fruit at lower temperatures than on green fruit. Later (*33*) they reported on studies at additional temperatures ranging from 32° to 86°, in which they obtained the same general retarding effect of low temperatures to development of decay. They observed that low temperatures had a greater retarding effect during the incubation period than during later development.

Since the temperature in the bottom layer of fruit in refrigerator cars has been shown to be appreciably cooler than in the top layer (p. 57) except when fan-type cars are used, less decay would be expected in the bottom layer. Brooks and Cooley (*33*) compared the amount of brown rot that developed in the top and bottom layers of 11 cars on arrival at destination. They found that the average percentage of sprayed fruit showing decay was 8 in the top layer and only 2.5 in the bottom layer. The corresponding figures for unsprayed peaches was 30 in the top layer and 13.5 in the bottom layer. In commercial lots they found about four times as much decay in the top layer as in the bottom layer of the loads.

In a later publication, Brooks (*30*) reported similar results with 3.4 percent of brown rot in the bottom layer and 16.3 percent in the third layer. The effect of temperature on brown rot during transit was greater than was obtained from similar temperature differences in holding tests. M. A. Smith (*198*) inoculated peaches with spores of the brown rot fungus and held them at constant temperatures of 40° to 85° F. Peaches rotted readily at all of the temperatures but more rapidly at the higher temperatures. W. H. Smith (*201*) observed that brown rot was negligible during storage at 32° and 37°, but that it developed more rapidly on peaches removed from cold storage to room temperature than on those ripened at room temperature without previous exposure to cold storage.

Haller and Harding (*82*) determined total decay on several varieties of peaches during four seasons in which some lots were ripened immediately at 70° F. and others were ripened at 70° after 1, 2, and 3 weeks at 32°. On removal from 32° storage no decay

was found. Although decay averaged somewhat less when the peaches were ripened at room temperature after a period in cold storage than when ripened immediately, the results were not consistent and the differences not statistically significant, except after 1 week in cold storage. The average percentages of decay (lots with at least 5 percent decay) were 29.5 when ripened immediately, and 15.0 when ripened after 1 week at 32° (11 comparisons); 33.1 for immediate ripening, and 25.4 when ripened after 2 weeks at 32° (16 comparisons); and 32.9 when ripened immediately, and 24.4 when ripened after 3 weeks at 32° (16 comparisons).

Further studies along this line were made by Mallison and Haller (*144*) with two varieties. When Belle peaches were placed at 70° F. immediately after picking, there was 15 percent decay by the time they were ripe. Those ripened at 70° following storage for 3, 6, and 9 days at 40° had 20, 26, and 19 percent decay, respectively. When the peaches were held at 32° for 3, 6, and 9 days before ripening at 70°, the percentages of decay were 27, 14, and 23, respectively. When Elberta peaches were placed immediately at 70° and ripened in 2 days to 3.8 pounds' pressure test, 39 percent of them were decayed. When they were ripened at 70° for 1 day to the same firmness, after being held for 9 days at 40°, they showed about 60 percent decay; and when ripened at 70° for 2 days, after being held for 9 days at 32°, they showed 53 percent decay. These results generally indicate higher percentages of decay when the fruit was ripened after a period under refrigeration than when ripened immediately. However, decay percentages generally vary greatly, and it is questionable whether these differences are statistically significant. Certainly, by the time the fruit is ripe, the data do not show any significant reduction in decay due to exposure to low temperatures.

Hienton and Fawcett (*105*) stated that precooling to below 50° F. will control brown rot on peaches in transit. Willison [20] listed precooling among measures to control brown rot, although he also stated that refrigeration is no substitute for orchard-control measures. He indicated that low temperatures prevent spore germination but do not stop the growth of the organism. In a later report, Willison (*229*) found that there was less brown rot on peaches held at 33° than on those held at 45°, and very much less at 45° than at room temperature. He observed that infection by the brown rot organism could occur at temperatures as low as 33°, but that the incubation period was long. He stated that temperatures of 45° or lower will delay infection long enough for commercial purposes.

Redit, Haller, and Kaufman (*182*) found that precooling did not significantly reduce decay in peaches shipped in three-layer loads of either bushel tub baskets or bushel wire-bound (Spartan) boxes. However, the precooling did not appreciably hasten the cooling of the load as compared with loads not precooled.

[20] See footnote 8, p. 15.

Hitz, Simons, and Schell (*108*) reported that brown rot of peaches was reduced by increasing the ventilation in baskets, presumably as a result of more rapid cooling. Decay was also less in bushel boxes than in standard ventilated baskets. They also found that cooling the peaches with ice water reduced decay, but only from an average of 40.6 percent to 30.3 percent in 27 comparisons. In a later report, Hitz and Johnson (*107*) presented additional data which indicated that increasing the ventilation in baskets decreased the percentage of brown rot on peaches, presumably by hastening the rate of cooling. They also showed that cooling the peaches for 8 hours significantly reduced the development of brown rot for 3 to 4 days.

Sharvelle and Burkholder (*192*) compared brown rot development in samples from several orchards when held at room temperature continuously for 4 days, and when held 1 day at 40° F. and followed by 3 days at room temperature. They stated that cold storage (40° for 1 day) greatly reduced the subsequent development of brown rot at room temperature. One example was given in which 41.8 percent of brown rot developed after 4 days continuous storage at room temperature, as contrasted with no brown rot after 1 day at 40° and 3 days at room temperature. They stated that similar results were obtained with other experimental lots. Hood and Heuberger (*110*) reported on similar tests in which peaches were held for 4 days at room temperature—after 1, 2, 3, and 4 days' storage at 40° for Halehaven, and after 1 and 2 days' storage at 40° for Elberta. Contrary to the results of Sharvelle and Burkholder (*192*), but in agreement with those of W. H. Smith (*201*), Haller and Harding (*82*), and Mallison and Haller (*144*), the results indicated that low-temperature storage had no pronounced effect on subsequent rotting at room temperature.

Peaches inoculated with spores of the brown rot organism were held by Hamilton (*87*) at 32°, 43°, 50°, 75°, and 82° F. for different periods. They were then placed in a moist chamber at 74° to determine the length of time the spores would remain viable at different temperatures. The results indicate that the effect of the temperature at which peaches are stored on the subsequent development of brown rot is correlated with the ripening process of the fruit rather than with fungal development. Hamilton stated that holding peaches for short periods at low temperatures had no effect upon the time required for infection to take place at room temperature.

In general, the results show that temperatures have a profound effect on the germination and development of the brown rot organism. Low temperatures greatly retard the germination of the spores and the development of the organism, but they apparently do not affect their viability. By the use of precooling and refrigeration in transit, it is possible to retard the development of decay so that the fruit reaches the market in a sound condition. However, as pointed out by Haller (*81*), refrigeration also retards the ripening of the fruit to about the same extent as

it retards fungal growth. He points out that when peaches are removed from refrigeration for ripening, the conditions favorable for the resumption of ripening are also favorable for spore germination and fungal growth. Consequently, the number of peaches that become ripe enough to use without decay is not increased by precooling and refrigeration in transit. Haller stated that "refrigeration [in transit] and possibly precooling may be necessary or desirable to retard ripening of the fruit, particularly when it is picked in an advanced stage of maturity, but the best interests of the peach industry are not served when refrigeration is mainly depended on to hold rot in check."

RHIZOPUS ROT

Relatively few studies have been made in which rot caused by *Rhizopus* has been differentiated from rot caused by the brown rot organism. Reports which discuss total decay have been referred to in the section just presented on brown rot on the assumption that the decay was predominantly brown rot. In other reports in which the decay has been designated as brown rot, some of it may have been rhizopus rot or other rots, since decay from natural infection is seldom restricted to brown rot. Lesions caused by *Rhizopus* and *Monilinia* are very similar in appearance in the early stages. At these stages they can be distinguished primarily by the ease with which light rubbing will cause the skin to slip from lesions caused by *Rhizopus* (*185*).

The *Rhizopus* fungus is able to grow on a wide variety of products and, since spores of the organism are universally present in the air, infection may occur at any time during the growth and marketing of the fruit. This rot differs from brown rot in that it is not an orchard disease. Inoculations may occur in the orchard, but the organism apparently is unable to attack the uninjured and unripe fruit. It may be possible for spores lodging on the fruit in the orchard to germinate after the fruit is picked and to cause decay as the fruit approaches ripeness. However, there appear to be no recent studies as to where inoculations that cause peaches to decay are most likely to occur. Other possible sources of inoculation are contaminated picking bags, field crates, and packing-house equipment. Studies on the extent to which inoculation occurs at these points would be desirable to determine the need for sanitation and disinfection.

Rhizopus rot, unlike brown rot, seems to be more prevalent during dry seasons. Brooks (*30*) compared the amount of rhizopus decay in commercial shipments during a relatively dry harvest season and during a relatively wet one. Rhizopus rot developed in 1 percent or more of the fruit in 27 and 12 percent of the cars inspected in the dry and in the wet seasons, respectively. Rose and others (*185*) stated that rhizopus rot is frequently the only rot seen in shipments of peaches grown in the dry (irrigated) sections of Colorado and other Western States.

In needle-point inoculations with *Rhizopus* spores, Brooks and Cooley (*32*) showed that this fungus develops more rapidly on

ripe peaches and on agar culture media than on unripe peaches. They suggest that *Rhizopus* is a saprophyte and suited to growth on inactive living material such as overripe fruit. In a later publication (*33*) they observed that rhizopus rot was not increased when the spores were dusted on uninjured peaches. They stated that, "It is the opinion of the writers that the unbroken skin of the peach furnishes a complete protection against Rhizopus, except in cases where the sound fruit is in close contact with that which is already decayed." Haller and others (*85*) came to similar conclusions following inoculation tests with *Rhizopus*.

Packing-House Control

Greve (*74*) found that total decay (predominantly rhizopus rot) was less in peaches packed in ventilated boxes than in nonventilated baskets. The average decay in six varieties after 56 hours at room temperature was 30 percent in the ventilated boxes and 46 percent in the baskets.

There are relatively few reports on the control of rhizopus rot by fungicidal treatment. Heiberg and Ramsey (*100*) tested the vapors of diphenyl against a number of organisms, including *Rhizopus nigricans,* in agar cultures. Growth of *R. nigricans* was inhibited by relatively low concentrations of the vapors, but the fungus was not killed. They suggested the use of diphenyl-impregnated wraps, pads, or packages for controlling diseases, but pointed out that the retention of the diphenyl odor would make its use impractical for many products. Some commercial shipments of peaches were made from Georgia in 1947 and 1948 in which diphenyl-impregnated liners and pads were used. The shipper indicated that good control of decay was obtained, but use of the liners and pads was discontinued because of reports of off-flavors in the fruit. Liners and pads impregnated with diphenyl, in which the odor was reduced, were tried in a holding test by Haller and others (*85*). Very good control of rhizopus rot was obtained, but the fruit had a distinct diphenyl flavor. It seems likely that a concentration of diphenyl high enough to control decay would also cause off-flavors in the fruit.

Vaughn and Hamner (*217*) used the antibiotic cycloheximide (Acti-dione) as a disinfectant treatment. Since decay of treated peaches was largely rhizopus rot and blue mold (*Penicillium* spp.) and decay of the untreated fruit was largely brown rot, the investigators concluded that the cycloheximide did not give lasting protection against the common molds, but that it was effective against the brown rot organism. In a report of postharvest treatments of peaches, Heuberger, Munger, and Poulos (*101*) stated that when rhizopus rot was present, treatment with Isothan Q 15 (lauryl isoquinolinium bromide) increased the amount of rot and that liquid lime sulfur had no effect. Haller and others (*85*) used a number of materials as postharvest dusts, sprays, or fumigants on peaches that were inoculated with *Rhizopus* spores. Although a number of the materials reduced brown rot on peaches inoculated with spores of the brown rot organism (pp. 75 to 84),

none of the materials (except diphenyl liners) significantly reduced rhizopus rot on peaches inoculated with spores of that organism. These results indicated that the *Rhizopus* organism is much more difficult to control by chemical means than the brown rot organism and that no fungicide that would be practical to use has been found to be effective.

One of the most serious aspects of rhizopus rot is its rapid spread. This may result in a nest of 10 to 20 or more peaches being decayed within 2 or 3 days at room temperature from a single primary infection. Haller and others (*85*) reported that rhizopus rot was greatly reduced by the use of copper-impregnated wraps, presumably by preventing spread of the rot to adjacent fruit.

Temperature Relationship

Considerable work has been done on the effect of temperature on the *Rhizopus* organism, and in general the results are similar to those obtained with the brown rot organism (see p. 85). Brooks and Cooley (*32*) studied the effect of temperature on both organisms growing on peaches. They found that low temperatures had an even greater retarding effect on *Rhizopus* than on the brown rot organism. At 68° F. the growth rate of both organisms was about equal. At 50° *Rhizopus* grew only about half as fast as the brown rot organism and at 45½° growth of *Rhizopus* was practically stopped. In a later publication, Brooks and Cooley (*33*) presented additional data confirming the results of their earlier tests. They showed that the optimum temperature (86° F. or above) for growth of *Rhizopus* was appreciably higher than that (about 76°) for the brown rot organism. They observed that low temperatures had a relatively greater inhibiting action upon development of *Rhizopus* during the incubation period than during later growth.

Brooks (*30*) has shown that the higher temperatures in the top of loads in standard (nonfan) refrigerator cars result in higher percentages of rhizopus rot in the top of the load as compared with the bottom. In commercial shipments of peaches in crates, there was 15.6 times as much rhizopus rot in the top (fourth) layer as in the bottom layer. In shipments in three-layer loads of baskets, rhizopus rot was 5.4 times as great in the top as in the bottom layers. The effect of the difference in temperature at the top and bottom of the loads was greater in the case of rhizopus rot than in the case of brown rot. This would be expected from the greater effect of temperature on the *Rhizopus* organism than on the brown rot organism, as observed under different constant-temperature conditions. As a control measure for rhizopus rot Brooks (*30*) suggested more effective refrigeration by precooling and the use of salt with the ice. The only method for control of rhizopus rot suggested by Rose and others (*185*) is also more effective refrigeration by precooling and the use of fan cars. Heuberger, Munger, and Poulos (*101*) stated that "storage at 42° gave perfect control" of rhizopus rot.

The use of refrigeration as a means of controlling rhizopus rot is open to the same criticism as its use to control brown rot, in that refrigeration does not kill the decay organisms but only retards their growth. In this connection, Brooks and Cooley (*32*) reported that peaches inoculated with *Rhizopus* spores and held at 45.5° F. were still free from rot at the end of 4 days, but when removed to room temperatures they were completely rotted by *Rhizopus* 2 days later.

In general, satisfactory control of rhizopus rot may be more difficult than that of brown rot, as rhizopus rot cannot be controlled by orchard spraying, and no effective fungicide has been found for postharvest treatment. Picking and handling the fruit so as to avoid skin breaks should help, as *Rhizopus* apparently is unable to penetrate the unbroken skin. Use of copper-impregnated wraps greatly reduced rhizopus rot by preventing its spread.

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